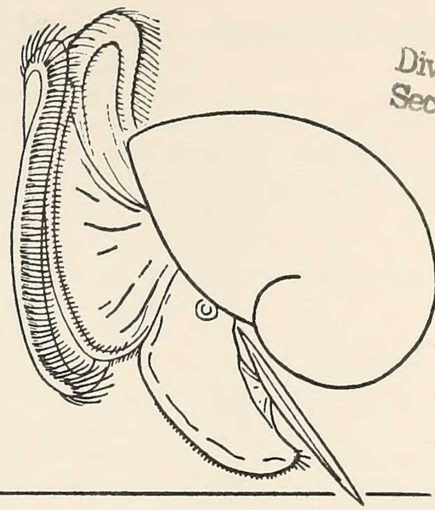
THE VELIGER



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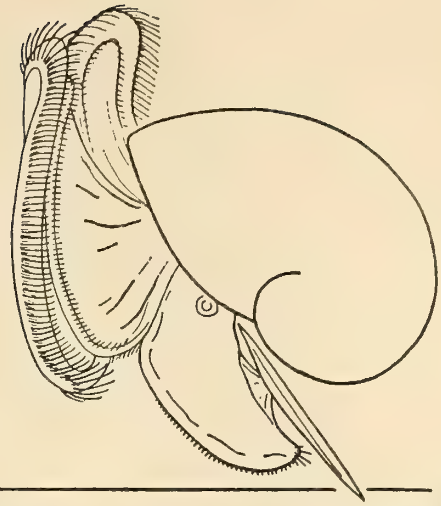

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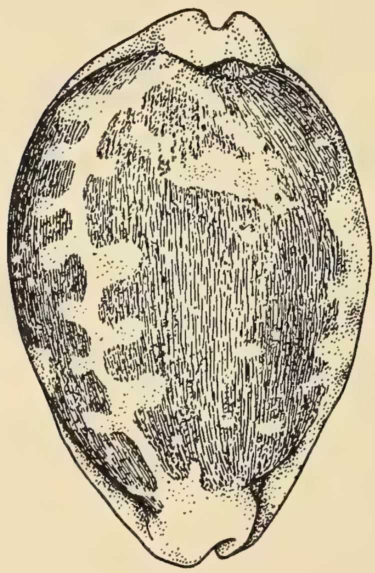

Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION, Subdivision,** SECTION,
SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).
New Taxa

The Fine Structure of the Follicle Gland of the Snail, *Lymnaea auricularia* (Mollusca: Gastropoda)

BY

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LEONARD SIMPSON
AND
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(Plates 1 to 4)

INTRODUCTION

THE FOLLICLE GLAND of the cerebral ganglion of pulmonate gastropods was first described by DE NABIAS (1898) and by PELSENEER (1901). It has recently been reinvestigated by LEVER and his colleagues in Amsterdam (LEVER, 1958; LEVER *et al.*, 1959; LEVER and JOOSSE, 1961) in several basommatophoran and stylommatophoran species. On the basis of light-microscope observations, LEVER has raised the possibility that the follicle gland is a neuro-endocrine organ with neurosecretory activities. WAUTIER *et al.* (1961) consider the gland in *Gundlachia* as devoted exclusively to secretion. In *Arion,* VAN MOL (1960) describes an equivalent structure as a non-neural endocrine organ (the "cephalic gland"), and this opinion is apparently shared by NOLTE (1963), who terms a similar organ "cerebral gland" in the Helicidae. However, an embryonic vesicle giving rise to neurons but disappearing in later development is also described by SANCHEZ & BORD (1958) in *Helix aspersa.* Whether all these cerebral vesicles represent the same entity is difficult to decide.

The present study of the ultrastructure of the follicle gland was undertaken initially in the hope of finding a simple neurosecretory system, spatially restricted in scope, in which the formation, transport, and release of neurosecretion could be studied in neurons with short axonal processes. In addition, the gross structural similarity of this gland to the epistellar body of the octopus and to the parolfactory vesicles of squids has raised the possibility that mollusks generally might possess a family of related vesicular organs associated with the nervous system (*cf.* NISHIOKA *et al.*, 1962; BERN & HAGADORN, 1964).

MATERIALS AND METHODS

The adult freshwater snails, *Lymnaea auricularia* (identified by Dr. R. Stohler), used in this study were collected from Grayson Creek near Concord, California. The specimens used for light microscopy were fixed in Stieve's and Helly's fixatives, embedded in paraffin, sectioned at 5μ and stained with paraldehyde fuchsin. The animals used for electron-microscope observations were fixed in 1% osmium tetroxide buffered with veronal-acetate (pH 7.5) and embedded in Maraglas-Cardolite (FREEMAN & SPURLOCK, 1962). Thin sections were cut on a Porter-Blum microtome, picked up on formvar-coated copper grids backed with carbon, stained with uranium acetate (WATSON, 1958) and lead citrate (REYNOLDS, 1963), and examined in a RCA EMU 3G electron microscope.

OBSERVATIONS

The follicle gland is located laterally in the lateral lobes of the cerebral ganglion, adjacent to the epineurial capsule. The follicle itself consists of a single layer of low columnar epithelioid cells surrounding an ovoid lumen (Figure 1). In adult specimens, the follicle has an average diameter of about 30μ, and its epithelial wall is about 10μ thick.

Paraldehyde fuchsin-positive colloidal material is present within the lumen. Most of this material is generally found just apical to the follicle cells. The presence of a low, irregular brush-border is discernible on the follicle cells in areas where only a small amount of colloid substance is present.

There were no neurons filled with paraldehyde fuchsin-positive droplets in the lateral lobe of *Lymnaea auricularia,* as have been described by LEVER (1958), LEVER *et al.* (1959), and LEVER & JOOSSE (1961) in several species of Basommatophora, including *L. stagnalis.* Only a haze of fuchsinophilic material was observed in a few neuron perikarya and axons. As a result neuronal processes were difficult to trace with certainty in our preparations. Most

of the nerve processes of the lateral lobe neurons appear to enter the neuropil of the adjacent cerebral lobe. Other processes were directed toward the follicle, but it could not be determined whether they terminated in association with the follicle.

Ultrastructural observations failed to establish the presence of neurosecretory material in the lumen of the follicle gland. Instead, the lumen is occupied by randomly-oriented microvilli and cilia, except for a small, clear central area (Figures 2 and 3). The branching microvilli extend from the apices of the epithelioid cells to form a dense network. Intermingled with the microvilli are cilia, which extend into the lumen from the processes of less common neuron-like cells that also contribute to the follicle wall.

The cytoplasm of the epithelioid cells is dense, except at the apical margin, and contains many ribosomes, some of which are associated with cisternae of the endoplasmic reticulum (Figures 4 and 5). The mitochondria and Golgi apparatus appear typical in form. Some multivesicular bodies and lysosome-like bodies are also present. The nuclei are generally ovoid, oriented perpendicular to the capsule.

The processes of the neuron-like cells can be distinguished from the cytoplasm of epithelioid cells owing to their lack of density (Figures 2 to 5). A few ribosomes are found in the cytoplasm, in addition to some small vesicles of variable size. The mitochondria are large and irregular in shape. The cristae are distantly spaced, thereby giving the mitochondria an empty appearance (Figures 4 and 5). The nuclei of the neuron-like cells are larger than those of the epithelioid cells. Some of the former cells are present within the capsule surrounding the follicle; the perikarya of others are presumably located outside the capsule (Figure 3).

The neurons present in the small area of the lateral lobe adjacent to the follicle were cursorily examined in the electron microscope. These neurons possessed the usual organelles, and some also contained numerous vesicles of assorted sizes. Certain of these neurons contained mitochondria resembling those found in the processes of the follicle gland. No typical elementary neurosecretory granules (electron-dense, in the 1000 to 3000Å range) were found in any of the neurons examined in the lateral lobe. However, many neurons with typical neurosecretory granules have been encountered in the cerebral ganglion proper.

DISCUSSION

The follicle gland of *Lymnaea auricularia* superficially has a neuroendocrine appearance at the light-microscope level. Lever (1958), Lever *et al.* (1959), and Lever & Joosse (1961) have studied this structure in several species of Basommatophora and Stylommatophora and have reported that an occasional bipolar neuron sends a process into the lumen; the lumen is often filled with densely-staining material, which they assume is neurosecretion.

On the electron-microscope level no electron-dense neurosecretory granules could be found in the follicle gland or in the lateral lobe of the cerebral ganglion in which it is located. The fuchsinophilia of the follicle contents is ascribed to accumulations of microvilli. The fuchsinophilic "secretion" of the octopus epistellar body also proved to be stacks of microvilli (Nishioka *et al.*, 1962).

It is of interest that de Nabias (1898) described the presence of cilia in the lumen of the follicle gland, which were attached to processes of the surrounding bipolar cells. To this pioneer investigator, the neuron-epithelium relation in the follicle gland was reminiscent of that seen in the vertebrate olfactory receptor.

It is conceivable that the masses of randomly arranged microvilli of the follicle gland located within the "brain" could reflect a former photoreceptive function of this structure, in an ontogenetic or a phylogenetic sense. Studies of the eye of two land gastropods, *Helix aspersa* (Eakin, 1963) and *Helix pomatia* (Röhlich & Török, 1963), have shown that their photoreceptors are rhabdomeric in type, composed of microvilli radially arranged on the sensory cell process. Although the molluscan photoreceptor is typically rhabdomeric, Clark (1963) has reported that the eye of *Viviparus maleatus* is of the ciliary type. Accordingly, the presence of cilia on the presumably neuronal processes extending into the lumen could also be in accord with a possible photoreceptive structure. However, it would be too facile to suggest that all closed vesicles, such as the follicle gland, associated with the protostome nervous system, are vestigial photoreceptors. In fact, the persistent follicles in gastropods are remnants of the embryonic cerebral tubes, at one time connected to the exterior. Some special sensory function of these structures (*cf.* de Nabias, 1898) is certainly conceivable, but there is no good basis for emphasizing photoreception.

A combined light- and electron-microscope study of neurosecretory phenomena in another basommatophoran snail, *Helisoma tenue*, now in progress, has demonstrated that the structural characteristics of the follicle gland in this animal are in accord with those described herein for *Lymnaea*.

In sum, the ultrastructural attributes of the follicle gland fail to support a neurosecretory role for this organ, and the data in favor of a photoreceptive function are meager at best. The true nature of the follicle "gland" remains unknown, but a sensory function of some sort, at least in embryonic life, remains a possibility.

SUMMARY

The follicle gland of *Lymnaea auricularia* has been investigated with the light and the electron microscopes for evidence of neurosecretory function. Paraldehyde fuchsin-staining material is present in the follicle gland. At the electron-microscope level numerous microvilli and some cilia are found projecting into the lumen from the cells forming the vesicle wall. Two cell types, one epithelioid and the other neuron-like, contribute to the make-up of the follicle. The microvilli project from the apical ends of the epithelioid cells, and the cilia are attached to processes of the neuron-like cells. No elementary neurosecretory granules were encountered in the follicle gland, and the role of the organ is enigmatic, although a sensory function in early life remains a possibility.

ACKNOWLEDGMENT

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LITERATURE CITED

Bern, Howard A. & Irvine R. Hagadorn

1964. Neurosecretion. Chapter 6 in Bullock & Horridge: Structure and function in the nervous system of invertebrates. W. H. Freeman Co., San Francisco (in press)

Clark, Allen W.

1963. Fine structure of two invertebrate photoreceptor cells. Journ. Cell Biol. **19:** 14A (abstract)

de Nabias, B.

1898. Recherches sur le système nerveaux des Gastéropodes Pulmonés aquatiques. Cerveau des Limnées (*Limnaea stagnalis*). Soc. Sci. d'Arcachon (Stat. Zool.): 43 - 72

Eakin, Richard M.

1963. Lines of evolution of photoreceptors. In: General physiology of cell specialization, D. Mazia and A. Tyler, *eds.*, 393 - 425, McGraw-Hill, New York

Freeman, James A. & Ben O. Spurlock

1962. A new epoxy embedment for electron microscopy. Journ. Cell Biol. **13:** 437 - 443

Lever, J.

1958. On the occurrence of a paired follicle gland in the lateral lobes of the cerebral ganglia of some Ancylidae. Proc. Kon. Ned. Akad. v. Wetensch., Amsterdam, C **61:** 235 - 242

Lever, J., H. H. Boer, R. J. Th. Duiven, J. J. Lammens & J. Wattel

1959. Some observations on follicle glands in pulmonates. Proc. Kon. Ned. Akad. v. Wetensch., Amsterdam, C **62:** 139 to 144

Lever, J. & J. Joosse

1961. On the influence of the salt content of the medium on some special neurosecretory cells in the lateral lobes of the cerebral ganglia of *Lymnaea stagnalis*. Proc. Kon. Ned. Akad. v. Wetensch., Amsterdam, C **64:** 630 - 639

Nishioka, Richard S., Irvine R. Hagadorn & Howard A. Bern

1962. Ultrastructure of the epistellar body of the octopus. Zeitschr. Zellforsch. **57:** 406 - 421

Nolte, A.

1963. Eine Cerebraldrüse bei Heliciden (Gastropoda). Licht- und elektronenoptische Untersuchungen. Gen. Comp. Endocrinol. **3:** 721 - 722 (abstract)

Pelseneer, P.

1901. Études sur des Gastéropodes Pulmonés. Mém. Acad. Roy. Belgique **54:** 1 - 76

Reynolds, Edward S.

1963. The use of lead citrate at high pH as an electron-opaque stain in electron microscopy. Journ. Cell Biol. **17:** 208 - 212

Röhlich, P. & L. J. Török

1963. Die Feinstruktur des Auges der Weinbergschnecke (*Helix pomatia* L.). Zeitschr. Zellforsch. **60:** 348 - 368

Sanchez, Simone & Colette Bord

1958. Origine des cellules neurosécrétrices chez *Helix aspersa* Mull. C. R. Acad. Sci. **246:** 845 - 847

Van Mol, J. - J.

1960. Étude histologique de la glande céphalique au cours de la croissance chez *Arion rufus* Linné. Ann. Soc. Roy. Zool. Belgique **91:** 45 - 55

Watson, M. L.

1958. Staining of tissue sections for electron microscopy with heavy metals. Journ. Biophys. Biochem. Cytol. **4:** 475 - 478

Wautier, J., M. Pavans de Ceccatty, M. Richardot, B. Buisson & M. - L. Hernandez

1961. Note sur les complexes neuro-endocriniens de *Gundlachia* sp. (Mollusque Ancylidae). Bull. Mens. Soc. Linn. Lyon **30:** 79 - 87

Explanation of Plate 1

Figure 1: Lateral lobe attached to portion of cerebral ganglion. Follicle gland (fg) containing small amount of fuchsinophilic material is outlined by broken line.
ca: capsule; cg: cerebral ganglion; ll: lateral lobe. Paraldehyde fuchsin with counterstains. x870.

Figure 2: Portion of follicle gland sectioned centrally to show dense concentration of microvilli and cilia projecting into lumen. Two epithelioid cells (ec) with nuclei and three processes of neuron-like cells (nc) are shown.

Explanation of Plate 2

Figure 3: Montage of an elongate follicle gland sectioned at the periphery of the lumen (lu). Microvilli and cilia fill the lumen which is divided into two parts in this plane of section. Neuron-like cells and processes (nc) are less dense and contain irregular mitochondria. Some neuron-like cells are located external to the follicle wall and send processes through the capsule into the lumen. Epithelioid cells (ec) have small nuclei and dense cytoplasm. Connective tissue capsule (ca) separates the follicle gland from the lateral lobe.

Explanation of Plate 3

Figure 4: Section through wall of follicle gland. Neuron-like cell processes (nc) contain irregular mitochondria (m_n) and less cytoplasmic structure. The epithelioid cell processes (ec) contain many ribosomes and typical mitochondria (m_e). Soma of a neuron-like cell, with its nucleus (n_n), as indicated by the nature of its mitochondria, is located at the bottom of the figure. Small double-walled cavities (mv) in cell processes presumably represent sections through bases of microvilli. c: cilium.

Explanation of Plate 4

Figure 5: Apical part of neuron-like cell processes (nc) with three cilia (c) and basal bodies (bb) are shown. Irregular mitochondria (m_n) are present in the process. Parts of two epithelioid cells (ec) containing many ribosomes are also shown. m_e: mitochondrion of epithelioid cell; mv: microvilli; ps: polystyrene particles.

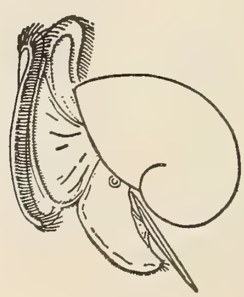

Figure 1

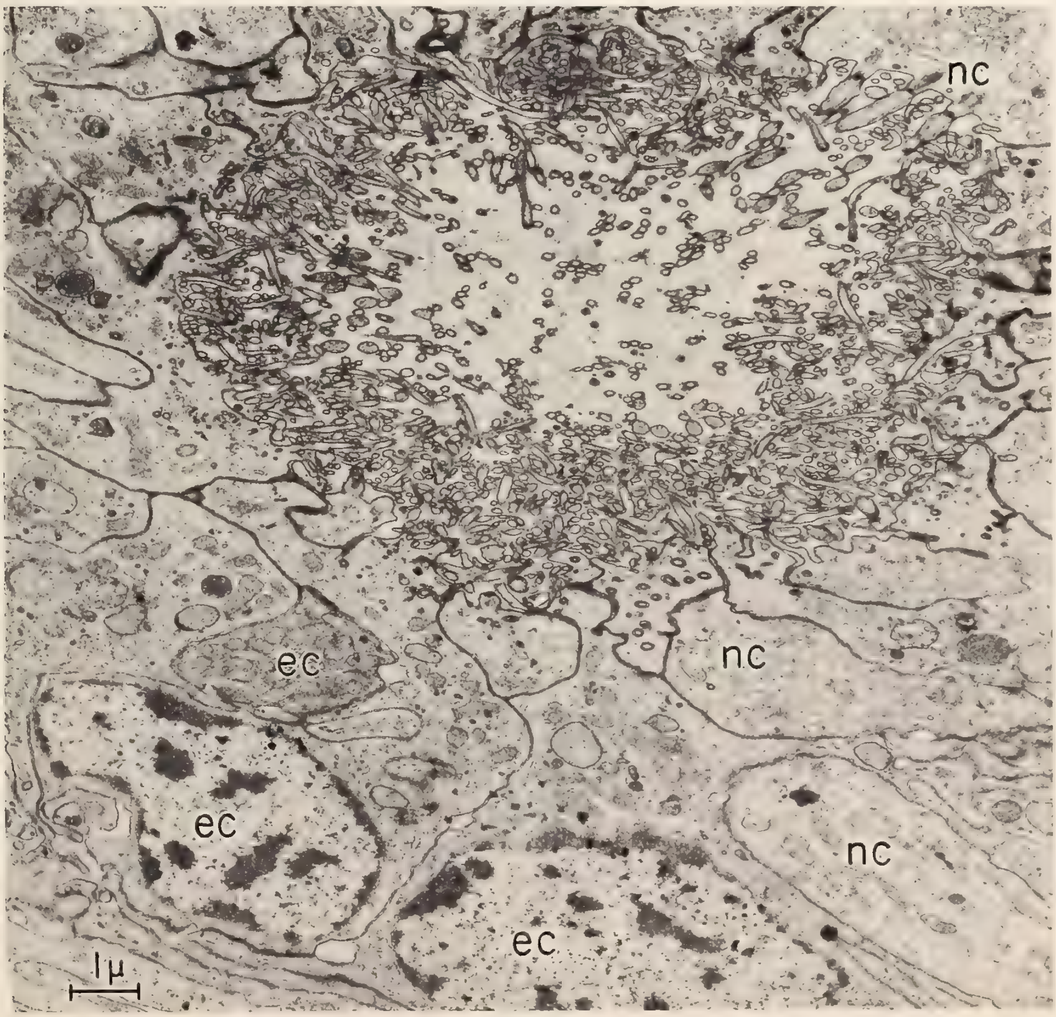

Figure 2

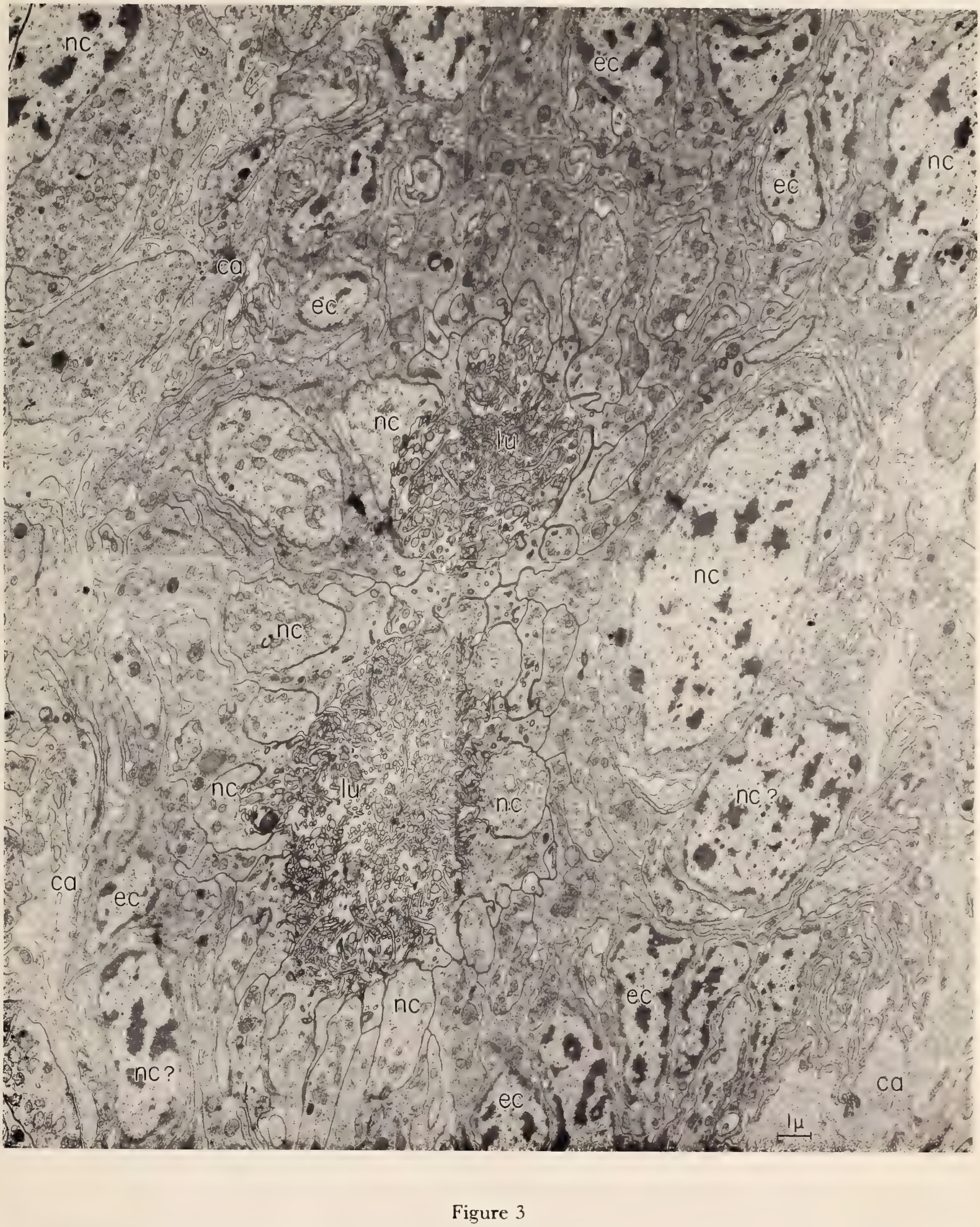

Figure 3

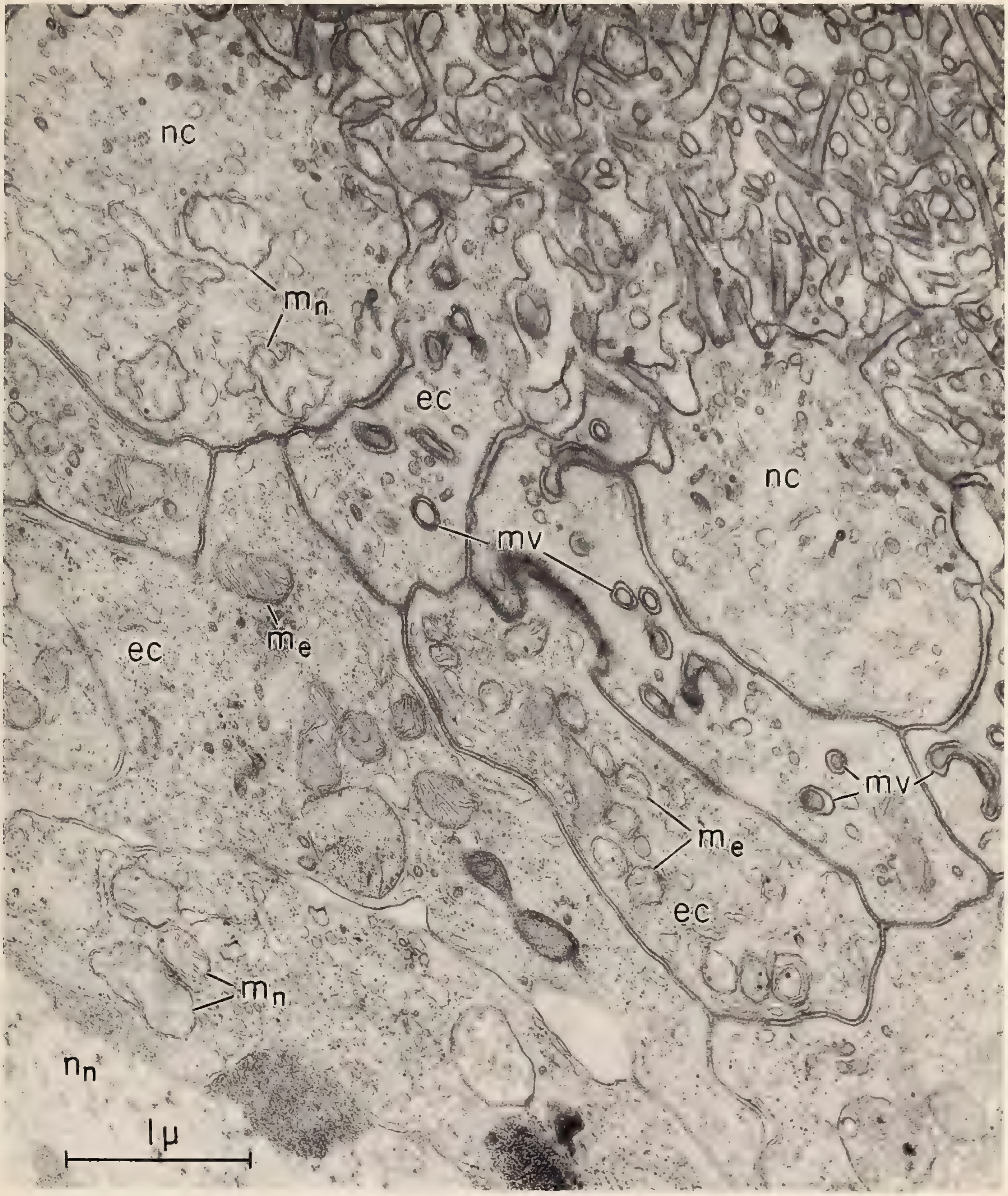

Figure 4

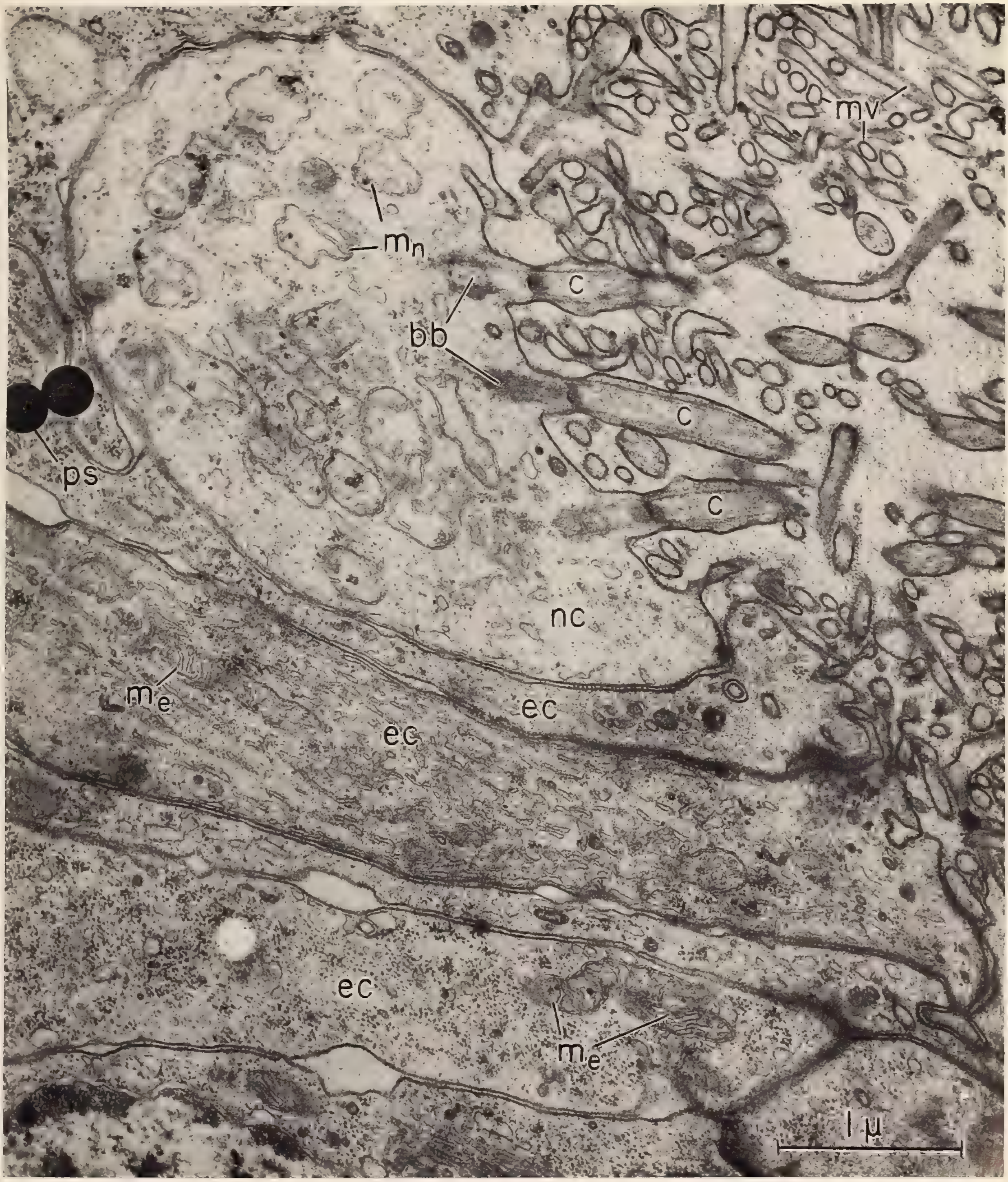

Figure 5

A New Name for *Murex rhyssus* Dall, 1919
(Mollusca: Gastropoda)

BY

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In a paper in this journal entitled "On the Identity of *Murex macropterus* Deshayes, 1839," I figured the type specimen and presented a synonymy of a related west American species that was described by Dall (1919) under the name of *Murex* (*Alipurpura*) *rhyssus* (see Emerson, 1964, p. 153, pl. 20, fig. 1). Mrs. Emily H. Vokes of Tulane University has kindly informed me that Dall's taxon is preoccupied by *Murex* (*Pteronotus*) *rhysus* [*sic*] Tate (1888), a fossil from the Tertiary of Australia. Under the present Code (Article 58, section 6), "Two or more species-group names of the same origin and meaning and cited in the same nominal genus or collective group are to be considered homonyms if the only difference in spelling consists of . . . the use of a single or double consonant" (Stoll, *et al.*, 1961, pp. 55, 56). I take pleasure in renaming *Murex* (*Alipurpura*) *rhyssus* Dall (1919) in honor of Mrs. Vokes, who is an avid student of the Muricacea.

***Pteropurpura* (*Pteropurpura*) *vokesae*,** new name

Murex (*Pteropurpura*) *petri* Dall, Dall, 1902, pl. 34, fig. 7 [U. S. N. M. cat. no. 122553]. Not *Murex petri* Dall, 1900.

Murex (*Alipurpura*) *rhyssus* Dall, 1919, vol. 56, p. 332; type locality: off San Pedro, California; type depository: holotype, in the U. S. National Museum, Washington, D. C., cat. no. 160500.

Murex (*Alipurpura*) *rhyssa* Dall, Oldroyd, 1927, p. 9, pl. 30, fig. 1 [figure of holotype].

Murex petri Dall, Oldroyd, 1927, pl. 28, fig. 7 [copy of Dall (1902), pl. 34, fig. 7]. Not *Murex petri* Dall, 1900.

Pteropurpura (?*Pteropurpura*) *rhyssa* (Dall), Emerson, 1964, p. 153, pl. 20, fig. 1 [figure of holotype]

Not *Murex* (*Pteronotus*) *rhysus* Tate, 1888, pp. 95, 96, pl. i, fig. 7.

Type locality: Off San Pedro, California by original selection of Dall (1919).

Holotype: U. S. National Museum, cat. no. 160500 by original designation of Dall (1919).

Remarks: This species has been dredged off the coast of southern California, from San Pedro to San Diego, in depths of 10 to 50 fathoms. Although beach specimens are rarely found, specimens sometimes are found in kelp holdfasts that have been washed ashore.

Before proposing a new name for Dall's taxon, I undertook to determine the biological validity of this species, which approaches some specimens of the *Ocenebra erinaceoides* complex, especially the form named *Murex californicus* by Hinds (1844a). Through the courtesy of Dr. Leo George Hertlein of the California Academy of Sciences and Mr. Emery P. Chace of the San Diego Natural History Museum, I recently examined the large series of specimens representing these taxa that are contained in the collections of these institutions. As a result of this study, I was able to conclude that Dall's taxon does not represent a northern population of the *Ocenebra erinaceoides* complex. In contrast to *Pteropurpura vokesae*, which occurs subtidally, *O. erinaceoides* (Valenciennes) occurs commonly in the intertidal zone, ranging along the west coast of Baja California at Scammon Lagoon, San Ignacio Lagoon, Santa María Bay, and Magdalena Bay and occurs in the upper half of the Gulf of California from Punta Peñasco, Sonora and Puertecitos, Baja California southward to Guaymas, Sonora and Concepción Bay, Baja California. These distributional patterns suggest that *Pteropurpura vokesae* is restricted to the subtidal waters of the Californian faunal province, whereas the northern populations of *O. erinaceoides* are apparently limited to the warm waters of several of the bays in the southern transitional zone of the Californian province and the subtropical to tropical waters of the extreme northern part of the Panamic faunal province.

It should be noted in passing that the original description of *Murex erinaceoides* Valenciennes (1832, p. 302) is largely undiagnostic, a conclusion reached by Carpenter (1857 a, p. 527) more than one hundred

years ago. Although VALENCIENNES did not illustrate this species, he did compare it with *Murex erinaceus* LINNAEUS from Europe and gave "Habitat ad portum Acapulco" [Guerrero, Mexico] for the type locality. CARPENTER (1857 b, pp. 170, 172) also pointed out that several of the species described by VALENCIENNES from Acapulco are foreign to Mexican waters, and the descriptions of the species were written nearly thirty years after the collections were made, a factor which might account for additional errors in VALENCIENNES' report. Inasmuch as specimens answering VALENCIENNES' description of *Murex erinaceoides* have not been subsequently reported from this section of the Mexican coast, an attempt should be made to locate and determine the identity of the type specimens of this taxon. *Murex californicus* HINDS (1844 a), on the other hand, was figured by HINDS (1844 b) and was cited from "California," presumably Baja California, Mexico. HERTLEIN (1953) briefly discussed the species of the *Ocenebra erinaceoides* complex and suggested that a subspecific name, *O. erinaceoides californica* (HINDS), be applied to specimens from Baja California.

In recent years, the trivaricate species that form the group of *Pteropurpura* generally have been placed in the muricid genus *Pterynotus* (*sensu lato*). This assignment, however, is not tenable owing to the presence of a purpuroid operculum in the group of *Pteropurpura* JOUSSEAUME (EMERSON, 1964). For the present time, I propose to recognize *Pteropurpura* as a polynominate genus in the subfamily Ocenebrinae for several groups of closely related species having three prominent varices (EMERSON, 1960).

ADDENDUM

I should like to take this opportunity to record a postscript to my recent paper on the identity of *Murex macropterus* DESHAYES (EMERSON, 1964). Dr. A. Myra Keen and Mr. James H. McLean of Stanford University have called my attention to the fact that BERRY (1956, p. 150) gave a historical review of this taxon and stated with reference to *Pteropurpura carpenteri* (DALL), "It appears not impossible that the oldest name for this species is *Murex macropteron* [sic] DESHAYES." Dr. Berry's conclusion apparently was based largely on comparisons of the Californian shells with drawings in REEVE (1845) and SOWERBY (1880), neither of which appears to represent the holotype of *Murex macropterus*. The original figures of *M. macropterus* (DESHAYES, 1841, pl. 38) were copied by KIENER (1843, *Murex* pl. 32, figs. 2, 2′). REEVE (1845, *Murex* pl. 27, sp. 123) figured a second specimen, from "the collection of Miss Saul." KÜSTER & KOBELT (1878, *Murex* pl. 34, figs. 10, 11) illustrated what may represent a third specimen. SOWERBY (1880, p. 24, *Murex* pl. 11, fig. 111) gave a poor copy of REEVE's figure and stated that there was another specimen in the British Museum (Natural History) which is probably the one figured by EMERSON (1964, pl. 19, fig. 3). TRYON (1880, pl. 40, fig. 517) presented a crude copy of REEVE's figure.

LITERATURE CITED

BERRY, SAMUEL STILLMAN

1956. Mollusca dredged by the *Orca* off the Santa Barbara Islands, California, in 1951. Journ. Washington Acad. Sci., 46 (5): 150 - 157; 9 figs. (May 1956)

CARPENTER, PHILIP PEARSALL

1857 a [1855 - 1857]. Catalogue of the collection of Mazatlan shells in the British Museum collected by Frederick Reigen. London; xvi + 552 pp. [July 1855 - June 1857, each part dated at foot of first page].

1857 b. Report on the present state of our knowledge with regard to the Mollusca of the west coast of North America. Rept. Brit. Assoc. Adv. Sci. for 1856: 159 - 368; plts. 6 - 9.

DALL, WILLIAM HEALEY

1900. A new *Murex* from California. The Nautilus 14: 37 - 38

1902. Illustrations and descriptions of new, or imperfectly known shells, chiefly American, in the U. S. National Museum. Proc. U. S. Nat. Mus. 24: 499 - 566; plts. 27 - 40.

1919. Descriptions of new species of Mollusca from the North Pacific Ocean in the collection of the United States National Museum. Proc. U. S. Nat. Mus. 56: 293 - 371

DESHAYES, GERARD PAUL

1841. Mollusques. Mag. Zool. d'Anat. Comp. et Palaeont.: plt. 38 and text.

EMERSON, WILLIAM K.

1960. Remarks on some eastern Pacific muricid gastropods. Amer. Mus. Novitates no. 2009: 15 pp.; 7 figs.

1964. On the identity of *Murex macropterus* DESHAYES, 1839 (Mollusca: Gastropoda). The Veliger 6 (3): 151 - 154; plts. 20, 21. (Jan. 1, 1964)

HERTLEIN, LEO GEORGE

1953. *Ocenebra erinaceoides* and allied species. [Abstract] Amer. Malacol. Union Ann. Report for 1953: 28 - 29.

HINDS, RICHARD BRINSLEY

1844 a. Descriptions of new species of *Scalaria* and *Murex*, from the collection of Sir Edward Belcher, C. B. Proc. Zool. Soc. London for 1843: 124 - 129 [March, 1844]

1844 b. The zoology of the voyage of H. M. S. Sulphur, under the command of Captain Sir Edward Belcher . . . during 1836 - 42. London, Mollusca, 2(1): 1 - 24; plts. 1 - 7 [July, 1844]

KIENER, L. C.

1843. Spécies général et iconographie des coquilles vivantes. Genre Rocher; 130 pp., 47 plts.

KÜSTER, H. C., & WILHELM KOBELT

1878. Mollusca Gasteropoda Purpuracea. Systematisches Conchylien-Cabinet. Nuremberg, 3 (2): 1 - 336; plts. 1 - 77.

Oldroyd, Ida Shepard
1927. The marine shells of the west coast of North America. Stanford Univ. Publ. Univ. Ser., Geol. Sci., 2 (1): 1 - 297; plts. 1 - 29; 2 (2): 1 - 304; plts. 30 - 72

Reeve, Lovell Augustus
1845. Conchologia Iconica. London, 3, *Murex*: plts. 1 - 36; 1 suppl. plt.

Sowerby, George Brettingham (second of name)
1880. Thesaurus conchyliorum, or monographs of genera of shells. London, 4 (pts. 33, 34), *Murex*: 1 - 55; plts. 1 - 24.

Stoll, N. R., *et al.*
1961. International Code of Zoological Nomenclature adopted by the XV International Congress of Zoology. London; xvii + 176 pp.

Tate, Ralph
1888. The gastropods of the older Tertiary of Australia. (Part 1). Trans. and Proc. and Report, Roy. Soc. South Australia, for 1886 - 1887, 10: 91 - 176; plts. i - xiii.

Tryon, George Washington, Jr.
1880. Manual of conchology. Philadelphia, ser. 1, 2, Muricinae, Purpurinae: 1 - 289; plts. 1 - 70

Valenciennes, A.
1832. Coquilles univalves marines de l'Amérique Equinoxiale. *In* Humboldt, F. H. A. von, & A. J. A. Bonpland, Voyage aux régions équinoxiales du Nouveau Continent. Paris, pt. 2, Recueil d'observations de zoologie et d'anatomie comparée: 2: 262 - 339; plts. 53 - 57.

Western Australian Cowries

(Mollusca: Gastropoda)

BY

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(Plate 5; 1 Map)

A search of pertinent literature reveals that little is known about the distribution of the cowrie fauna of Western Australia. Since Menke's report "Mollusks of Nova Hollandia" (1843), most of the studies and research on Australian mollusks has been confined to the southeastern and Queensland regions. H. F. Angas worked on this area from 1865 to 1878; John Brazier, from 1872 to 1875; and Charles Hedley, from 1894 to 1908. The work of Angas was restricted principally to the study of cowrie distribution in the area of Port Jackson (Sydney); Brazier referred to the western species rather generally, and with incomplete data; Hedley seems to have produced the first checklist of Western Australian *Cypraea*, drawing upon the reports of other authors to compile his list of 34 species. All these lists furnish information about certain species found at different points in the western area but deal largely in generalities where locality is concerned, and in some instances other data are vague or lacking.

During the past three years, with the able assistance of active collectors in the field, I have endeavored to bring the records up to date, compiling a list of verified species and localities, determining when possible the population centers, and recording other pertinent data not previously published. The present paper is not intended to be an exhaustive treatment of the Cypraeidae of Western Australia but an attempt to furnish as complete a list as possible of the different known forms. These records will be based entirely upon the field work of men known to me personally and upon specimens in my own collection that carry reliable collecting data.

From the beginning I have had the enthusiastic assistance of one of the most active collectors of *Cypraea* in Western Australia, Mr. A. R. Whitworth; his help has provided the basic framework for nearly all of the present study. I have also had substantial help from Mr. Ted Crake of Broome, who has contributed generously with specimens, maps, and information on ecology. Locality records for specimens not collected by either Whitworth or Crake have been verified though correspondence with the late B. E. Bardwell of Broome or with other reliable collectors. Some of the records were furnished by Dr. Tom Richert and Mr. Clifton S. Weaver of Honolulu, who collected 29 species of *Cypraea* at Long Island in Exmouth Gulf while participating in the Davina Expedition in 1960. Special thanks are also due to Dr. F. A. Schilder, who very kindly furnished his manuscript list of Western Australian cowrie species as well as his statis-

tics for a comparative study of *Cypraea caputserpentis reticulum* GMELIN, 1791 and *C. c. kenyonae* SCHILDER & SCHILDER, 1938, two races whose ranges apparently overlap to a certain extent along a part of Australia's west coast.

Although I originally intended to prepare only a checklist of cowrie species from the Exmouth Gulf area where most of our field work was done, I have more or less been obliged to extend the boundaries of the area studied in order to encompass the natural ranges of the various species; therefore the area covered here is from Cape Leeuwin in the south to Port Darwin in the north, the latter locality having been generally recognized as the northern limit of the Dampierian Region.

The actual presence of several species reported from Western Australia is yet unverified. Since this paper deals only with unquestionably reliable records, several given in the literature have been omitted intentionally, pending collection of additional material. They include such species as *Cypraea contaminata* SOWERBY, 1832, *C. childreni* GRAY, 1825, *C. gangranosa* DILLWYN, 1817, *C. maculifera* SCHILDER, 1932, *C. mauritiana regina* GMELIN, 1791, *C. felina* GMELIN, 1791, *C. microdon* GRAY, 1828, *C. interrupta* GRAY, 1824, *C. scurra* GMELIN, 1791, *C. punctata* LINNAEUS, 1771, *C. thersites contraria* IREDALE, 1935, *and C.* (*Umbilia*) *armeniaca* VERCO, 1912.

For the most part, Western Australia is a lonely, virgin coastline with scores of islands, reefs, bays, and jutting headlands. The tides along these coasts vary greatly; along the south and southwest coasts diurnal tides predominate, the rise averaging two and a half feet or less — the least tides in all Australia. In the vicinity of the and northwest coasts the tides are mainly of the regular or semi-diurnal type, with a maximum range at Collier Bay of 36 feet — the largest tides in all Australia. These unusual tides unquestionably have some effect on the distribution of molluscan species, and may in part explain the large gap in occurrence of certain cowrie species that would normally be expected to have a continuous range from North West Cape northward, but it would be premature at this time to theorize on the reasons for some of the unexplained problems of this particular fauna. Far more study is needed before an accurate picture may be obtained; the present paper is only a first step toward this goal.

Since the long coastline of Western Australia remains largely uninhabited, many of its landmarks and localities are known only by local names not found on any maps. Therefore it became necessary to devise some method of locating many of the collecting stations mentioned; this has been accomplished through an index of the presently accepted place-names, arranged in alphabetical order, each followed by its latitude and longitude bearings. Some of the more important of these have been indicated on the accompanying map.

Many of the listings of species in this paper extend the known range for those species considerably. Several represent potential new geographical races, one of which, a *nomen nudum,* has been given a new name. Another, because of its morphological differences and apparent geographical isolation from its nearest typical form, has been described as a new subspecies.

The largest and smallest shells of each species used in this study have been measured with a caliper to within one-tenth millimeter. It can probably be assumed that typical Western Australian examples of those species will vary in size somewhere between the two extremes given. Population densities are indeterminable at this time for some of the species, but perhaps some indication of relative abundance or scarcity may be gleaned from the number of specimens made available to me; this is mentioned under the discussion of each species.

ACKNOWLEDGMENTS

My thanks are extended to many people for their help. In addition to those already mentioned, I want to express my thanks to Mrs. Emily Reid for adapting a crude drawing into an excellent map; to Dr. Myra Keen for taxonomic advice; to Dr. Rudolf Stohler for translating source material and to Jean Cate whose extensive assistance in many ways made this work finally possible. It can well be said that this report would not have been completed without their combined interest and effort.

Index of Localities of West Australian *Cypraea*

This list is arranged alphabetically. In the subsequent discussion of the various species, reference is made to these localities by their order numbers only; moreover, the localities are listed there according to the relative abundance of the species, i.e., the locality where the species is most common is listed first.

		S. Lat.	E. Long.
1	Abrolhos Islands	28°31′	113°45′
2	Albany	34°57′	117°58′
3	Anson Bay	13°20′	130°08′
4	Barrow Island	20°41′	115°26′
5	Beagle Bay	16°55′	122°31′
5a	Black rocks	24°32′	113°27′
6	Botany Bay	33°58′	151°13′
7	Broome	17°59′	122°14′
8	Buccaneer Archipelago	16°15′	123°15′
9	Bunbury	33°20′	115°37′
10	Busselton	33°39′	115°20′
11	Cable Beach	17°57′	122°12′30″
12	Cambridge Gulf	14°55′	128°15′
13	Cape Bossut	18°42′	121°37′
14	Cape Cuvier	24°13′30″	113°24′

	S. Lat.	E. Long.
15 Cape Jaubert	19°02′	121°30′30″
16 Cape Leeuwin	34°22′	115°08′
17 Cape Leveque	16°24′	122°55′
18 Cape Naturaliste	33°32′	115°00′
19 Cape Vallaret	18°10′30″	122°10′30″
20 Carnac Island	32°07′	115°40′
21 Carnarvon	24°58′	113°40′
22 Carpentaria Gulf	15°00′	138°00′
23 Cervantes Island	30°32′	115°03′
24 Clifton's Main Reef	33°31′05″	115°24′30″
25 Clifton's Reef, Outer Knob	33°31′05″	115°24′28″
25a Collier Bay	16°10′	124°15′
26 Cottesloe Island	32°00′	115°46′
27 Daley Heads	locality unknown; see ALLAN, 1956	
28 Dampier Archipelago	20°33′	116°35′
29 Dampier Island (Reef)	25°24′	113°04′
30 Depuch Island	20°38′	117°42′
31 Dirk Hartog Island	25°45′	113°00′
32 Disaster Bay	16°55′	123°12′
33 Dunsborough	33°46′	115°05′
34 Eagle Hawk Island	20°39′	116°27′
35 Eighty Mile Beach	19°35′	121°00′
36 Encounter Bay	35°38′	138°42′
37 Entrance Point	18°01′	122°13′
38 Esperance	33°40′	121°58′
39 Eucla	31°40′	128°46′
40 Exmouth Gulf	22°00′	114°15′
41 Fort George	see Port George	
42 Fremantle	32°04′	115°45′
43 Gantheaume Point	17°59′	122°11′
44 Garden Island	32°12′	115°41′
45 Geographe Bay	33°34′	115°10′
46 Geraldton	28°47′	114°12′
47 Gourdon Bay	18°26′	121°52′
48 Houtman Rocks (Abrolhos)	28°31′	113°45′
49 King Sound	16°50′	123°25′
50 Lagrange Bay	18°35′	121°42′
51 Lancelin Island	30°59′	115°19′
52 Leighton Beach	31°58′	115°15′
53 Long Island	21°37′	114°40′
54 Low Point	17°47′	122°12′
55 Ludlow Beach	32°00′	115°45′
56 Monte Bello Islands	20°25′	115°31′
57 Nickol Bay	20°40′	116°55′

	S. Lat.	E. Long.
58 Normanville	locality unknown	
59 North West Cape	21°47′	114°10′
60 Onslow	21°40′	115°07′
61 Old Onslow	21°43′	114°56′
62 Peak Island	21°45′	114°25′
63 Pelsart Island	28°30′	113°45′
64 Point d'Entrecasteaux	34°51′	116°00′
65 Point Maud	23°08′	113°46′
66 Point Murat	21°49′	114°11′
66a Point Samson	20°36′	117°10′
67 Point Willunga	locality unknown	
68 Port Darwin	12°28′	130°45′
69 Port Essington	10°05′	132°30′
69a Port George IV	15°25′	124°04′
70 Port Hedland	20°20′	118°35′
71 Port Walcott	20°37′	117°10′
72 Price's Point	17°47′	122°12′30″
73 Quobba Point	24°30′	113°26′
74 Recherche Archipelago	34°00′	122°30′
75 Riddell Point	18°00′	122°12′
76 Robert Point (Mandurah)	32°32′	115°43′
77 Roebuck Bay	18°05′	122°15′
78 Rottnest Island	32°00′	115°30′
79 Rowley Shoals	17°10′40″	118°50′ to 119°40′
80 Sandy Point	18°13′	122°11′
81 Shark Bay	25°30′	113°30′
82 Sorrento Reef	31°30′	115°30′ (approx.)
83 Spencer Gulf	33°55′	137°22′
84 St. Vincent Gulf	34°55′	138°10′
85 Stradbroke Island	27°35′	153°29′
86 Sunday Island	16°25′	123°11′
87 Swan River	32°04′	115°45′
87a Thevenard Island	21°27′	115°00′
88 Torres Strait	10°00′	142°30′
89 Troughton Island	13°04′	126°09′
89a Turtle Dove Shoal	29°04′	114°52′
90 Vlaming Head	21°48′	114°07′
91 Walcott Inlet	16°22′	124°30′
92 Wallaby Islands	28°27′	113°40′
93 Ward Reef	21°32′	115°10′
94 York Sound	14°55′	125°07′


120°
130°
10°
20°
30°
NETHERLANDS INDIES
TIMOR
TIMOR SEA
Port Darwin
INDIAN OCEAN
BUCCANEER ARCH.
CAPE LEVEQUE
ROWLEY SHOALS
KING SOUND
NORTHERN TERRITORY
ROEBUCK BAY
Broome
LAGRANGE BAY
DAMPIER ARCH.
MONTE BELLO IS.
Port Hedland
VLAMING HEAD
NORTH WEST CAPE
EXMOUTH GULF
TROPIC OF CAPRICORN
QUOBBA PT.
Carnarvon
SHARK BAY
DIRK HARTOG ISLAND
WESTERN AUSTRALIA
SOUTH AUSTRALIA
Geraldton
HOUTMAN ABROLHOS IS.
Eucla
SORRENTO REEF
Perth
Swan R.
ROTTNEST IS.
GARDEN IS.
Fremantle
GEOGRAPHE BAY
Esperance
CAPE NATURALISTE
CAPE LEEUWIN
Albany
GREAT AUSTRALIAN BIGHT
INDIAN OCEAN

Index of Species and Subspecies

CYPRAEIDAE

Nariinae

Pustularia SWAINSON, 1840

(*Pustularia* SWAINSON, 1840)

1. *Pustularia* (*P.*) *cicercula cicercula* (LINNAEUS, 1758)

Syst. Nat., Ed. 10, p. 725

Localities **90**, **59**

WEAVER (1960): **53**

	L	W	H	lip	col[1]
Largest shell:	19.0	13.3	12.0	26	22
Smallest shell:	16.2	11.6	10.5	28	24

Two shells were examined that were picked up in the beach drift in the immediate area below the Vlaming Head lighthouse. As far as I have been able to determine, the WEAVER (1960) report represents the first mention of the species in Western Australia. IREDALE (1939) stated "I recorded *Pustularia cicercula* and *P. globulus* from Queensland, the latter only from Western Australia." ALLAN (1956) cited northern Australia.

The western shells seem to compare favorably with the morphology of the typical species. The dorsal pustulation and general appearance agree, although the shell is generally somewhat larger and more globular; the basal dentition extends deeply into the margins; the fossula is

[1] L = length of shell, in millimeters
W = width of shell, in millimeters
H = height of shell, in millimeters
lip = number of teeth on outer lip
col = number of teeth on columella, excluding terminal ridge

shallower and less concave though more heavily ribbed with teeth. Possibly the *Pustularia bistrinotata* SCHILDER & SCHILDER, 1937, reported by authors is a mistaken identification of this species.

2. *Pustularia* (*P.*) *globulus globulus* (LINNAEUS, 1758)
Syst. Nat., Ed. 10, p. 725
Localities **14, 73**
IREDALE (1939), ALLAN (1956): Western Australia
SCHILDER (1941): **7, 12, 79**

	L	W	H	lip	col
Largest shell:	12.7	8.1	7.1	26	18
Smallest shell:	11.9	8.0	7.2	29	18

Two shells were examined, both collected after a storm, washed up with beach rubble. This species is rare in West Australian waters. The western shells are small for the species and compare favorably with those from the Seychelle Islands; the eastern *Pustularia globulus* attains nearly twice this size. An additional dead specimen was taken on the beach at Quobba Point. At present, nothing further is known about its distribution on the west coast of Australia.

Staphylaea JOUSSEAUME, 1884
(*Staphylaea* JOUSSEAUME, 1884)

3. *Staphylaea* (*S.*) *staphylaea* (LINNAEUS, 1758)
Syst. Nat., Ed. 10, p. 725
Localities **40, 59, 90, 77**
COTTON (1950): **43** (B. E. Bardwell)
SCHILDER (1941): **88** (as *S. descripta* IREDALE, 1935)
ALLAN (1956): **43**
WEAVER (1960): **53**

	L	W	H	lip	col
Largest shell:	17.9	10.7	8.8	21	22
Smallest shell:	13.2	8.1	6.9	20	18

Five shells were examined. The Dampierian shells seem to be generally smaller though apparently typical of the species. The aperture is narrower than that of *Staphylaea staphylaea descripta* and the shell more compact in form.

4. *Staphylaea* (*S.*) *limacina facifer* (IREDALE, 1935)
Austral. Zool., **8** (2): 119; plt. 8, fig. 6
Localities **40, 48, 90, 59, 7**
SCHILDER (1941): **88**

	L	W	H	lip	col
Largest shell:	18.2	10.3	8.2	19	15
Smallest shell:	13.6	8.2	6.8	20	18

Three shells were examined. The species is fairly common; the center of distribution for this subspecies appears to be from the southern shore of Exmouth Gulf to Vlaming Head, an extreme extension of range for the subspecies which is apparently living in this area as an isolated geographical group. The shells are conspicuous because of their smaller size in comparison with the other races.

(*Nuclearia* JOUSSEAUME, 1884)

5. *Staphylaea* (*N.*) *nucleus nucleus* (LINNAEUS, 1758)
Syst. Nat., Ed. 10, p. 724
Localities **40, 93**
WEAVER (1960): **53**

	L	W	H	lip	col
Shell measurements:	22.7	14.0	11.2	21	19

One shell was examined. So far as it is now known the species is rare. A single dead bleached and beach-worn specimen was collected at Point Murat in Exmouth Gulf. Although subfossil, the shell is sufficiently well preserved to exhibit the species' typical morphological characters, including the yellow-buff color above the terminal openings. The shell appears more bulbously inflated than any of the other subspecies studied; the teeth are fewer, and considerably shorter on the base as well. This is an extreme extension of range for the species, which was apparently first recorded from Western Australia by WEAVER (1960), from beach drift at nearby Long Island. Whitworth has also reported a third dead specimen collected at Ward Reef.

Erosaria TROSCHEL, 1863
(*Ravitrona* IREDALE, 1930)

6. *Erosaria* (*R.*) *labrolineata labrolineata* (GASKOIN, 1849)
Proc. Zool. Soc. London for **1848: 97** (13 March, 1849)
Localities **90, 59, 40**

	L	W	H	lip	col
Largest shell:	19.8	11.6	9.8	18	17
Smallest shell:	15.0	9.0	7.6	16	11

Five shells were examined, two from Vlaming Head and three from Exmouth Gulf. Although it would constitute a long range extension, I have grouped these shells with those of the nominate subspecies after comparing them with *Erosaria labrolineata nashi* IREDALE, 1931. The Dampierian shells are narrower; the lateral edge of the right margin is more sharply angled yet less pronounced; the teeth are finer, particularly on the base and do not cross the fossula as they do in the *E. l. nashi* of eastern Australia; the lateral spots are also more numerous.

7. *Erosaria* (*R.*) *cernica viridicolor* (CATE, 1962)
The Veliger **4** (4): 175; plt. 40, figs. 1 - 9
Localities **73, 90, 59, 40, 62, 42, 5a, 87a, 89a**

	L	W	H	lip	col
Largest shell:	28.2	18.5	13.8	20	17
Smallest shell:	16.0	10.0	8.1	16	15

Forty-one shells were examined. The subspecies appears to be common at only one station, as far as we have been able to determine; this is just below the lighthouse at Vlaming Head, which is the type locality. Shells were also collected in Exmouth Gulf, to Point Murat. It has been collected by Barry Wilson in 70 feet of water, under stones, off Peak Island. A dead specimen was found on the beach near Fremantle, also by Mr. Wilson (personal communication).

8. *Erosaria* (*R.*) *helvola citrinicolor* IREDALE, 1935
Austral. Zool., **8** (2): 116
Localities **40, 90, 59, 18, 46, 31, 49, 7**
HEDLEY (1915) *ex* BRAZIER, 1882: **79**
IREDALE (1939): **31, 81**
SCHILDER (1941): **45, 42, 87, 81, 46, 21, 68**
STEADMAN & COTTON (1946): Northwest Australia
ALLAN (1956): Western Australia
WEAVER (1960): **53**

	L	W	H	lip	col
Largest shell:	22.0	14.9	10.3	18	12
Smallest shell:	16.9	11.0	8.9	17	13

Twenty-eight shells were examined. Although this subspecies is widely distributed along the western coast, it cannot be classed as common. Exmouth Gulf proved to be the most productive among the localities cited above. Six shells were collected at Broome, Roebuck Bay over a two-month period; none have been seen since that time. BRAZIER (1882) erroneously referred to this form from Rowley Shoals as *Cypraea citrina* GRAY, 1824, confusing it with the distinct east African species. According to ALLAN (1956), COTTON has examined series of these shells from Cottesloe and Rottnest Island which he considered typical of *Erosaria helvola helvola* (LINNAEUS, 1758). A specimen from Leighton, however, was considered by him to be typical of IREDALE's subspecies.

9. *Erosaria* (*R.*) *caputserpentis reticulum* (GMELIN, 1791)
Syst. Nat., Ed. 13, p. 3407
Localities **90, 59, 40, 73, 7, 43, 11, 5, 17**
KENYON (1898), IREDALE (1935), and ALLAN (1956): Western Australia
IREDALE (1914): **56**
HEDLEY (1915); **44** (*ex* MENKE, 1843); **46** (*ex* VERCO, 1914)
SCHILDER (1941): **7, 12, 79**
COTTON (1950): **40**

	L	W	H	lip	col
Largest shell:	34.2	25.0	17.6	18	12
Smallest shell:	31.2	22.4	15.7	15	11

Seventy-two shells were examined. This common species ranges generally from south of Cape Naturaliste to Cape Leveque. It seems to possess interesting morphological differences at opposite ends of its range; certain physical aspects become sufficiently altered to divide the species into two distinct allopatric races. The area of Exmouth Gulf to Shark Bay seems to be the middle ground where examples of both forms may be found mingling and living together as individuals, yet at the same time intergrading variants are also present. The two subspecies involved are *Erosaria caputserpentis reticulum* (GMELIN) and *E. c. kenyonae* SCHILDER & SCHILDER, 1938. Dr. Schilder has very kindly given me permission to quote from his reply to a letter of mine: "Since 1938 I have examined far more specimens which alter our views in some respects: *kenyonae* is a race which exhibits no geographical exact limits separating its populations from those of *caputserpentis* (*reticulum*) but it is a so called "cline": the populations gradually pass from pure *caputserpentis* in the tropics to pure *kenyonae*, which seems restricted to southwest Australia, between Abrolhos Archipelago to Pallinup and C. Entrecasteaux on the south coast. In northwest Australia from Broome to Shark Bay the populations exhibit an increasing number of extreme shells which agree in all characters with the true *kenyonae*, while true *caputserpentis* become gradually less frequent, mostly replaced by intermediates in one or the other respect. One cannot say that the two "races" are living together, as there is one population with a range of variation from *caputserpentis* to *kenyonae*, so that it may be called intermediate. These intermediate populations show increasing influence of the warm *caputserpentis* and the cold *kenyonae*, according to its habitat further north or south. On the east coast of Australia from Torres Strait to Sydney there is a similar passing of *C. caputserpentis argentata* DAUTZENBERG - BOUGE, 1933 into *C. caputserpentis caputanguis* PHILIPPI, 1849."

The base of these shells is relatively flat; the terminals are greyish-blue, the base a pastel variation of yellow-orange, beige and white; the teeth are finer, more delicate, and are white; the interstices and more of the base are white as well.

10. *Erosaria* (*R.*) *caputserpentis kenyonae* SCHILDER & SCHILDER, 1938
Proc. Malac. Soc. London, **23** (3): 136; *ibid.* **3**: 77, fig. 2
Localities **40, 90, 59, 73, 7**

Cotton (1950): **52, 26, 78**
Allan (1956): Western Australia
Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	41.8	29.7	22.1	19	14
Smallest shell:	22.3	14.9	12.0	15	12

Twenty-eight shells were examined. This common subspecies merges with *Erosaria caputserpentis reticulum* (Gmelin, 1791) in Roebuck Bay, becoming increasingly isolated southward from Quobba Point to Cape Naturaliste (see preceding subspecies, *E. c. reticulum*).

This subspecies may easily be identified by its more swollen base; the teeth are white and much larger and heavier; most of the base, the interstices, and the terminals are brown. As a standard for separating these shells from *Erosaria caputserpentis reticulum*, it may be said that any trace of brown in the interstices would align the shell with *E. c. kenyonae*.

(*Erosaria* Troschel, 1863)

11. *Erosaria* (*E.*) *poraria poraria* (Linnaeus, 1758)
Syst. Nat., Ed. 10, p. 724
Localities **40, 90, 59**
Schilder & Schilder (1938 - 39): Northwest Australia.

	L	W	H	lip	col
Largest shell:	18.6	12.1	9.5	21	15
Smallest shell:	14.2	8.8	7.1	18	12

Five shells were examined. This species is rather uncommon and, as far as we have been able to determine, is not plentiful anywhere along the west coast. Kenyon (1879) published the new name *Cypraea wilhelmina* for a small pallid shell that both Iredale (1939) and Allan (1956) suspect is a dead specimen approaching *Erosaria poraria*. Bernard C. Cotton (personal communication) says his conclusion agrees with that of Iredale in which *E. wilhelmina* is a pale variant of *E. poraria*. The holotype of the Kenyon species is in the South Australian Museum, No. D 14447. Mrs. Kenyon stated that she had four other specimens very similar to the type. The shells from the North West Cape and Exmouth Gulf seem to be generally smaller than the northern and far western races, although there is an occasional large specimen. The dorsum is a deep, lustrous brownish-yellow flecked with a thick concentration of white spots, some of which appear to be ocellated with a darker brown ring. The margins are thickened, the right one being pitted. The base and margins are a deep, rich, intense lavender color, the teeth and interstices are white.

12. *Erosaria* (*E.*) *erosa purissima* (Vredenburg, 1919)
Journ. Asiat. Soc. Bengal, **15:** 143
Localities **7, 37** to **11, 40**
Iredale (1914): **56**
Hedley (1915): **56** (*ex* Iredale, 1914)
Iredale (1935): **40, 71, 29**
Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	46.9	27.5	20.0	20	15
Smallest shell:	36.8	22.2	16.7	17	14

Twelve shells were examined. The species is fairly common. Although this species seems to be living in a restricted geographical area, it compares very favorably with the eastern Australian shells and is considered conspecific, pending further study. *Erosaria erosa phagedaina* (Melvill, 1888), of Cocos Island, should also be compared with these, as it also closely resembles the Dampierian form.

13. *Erosaria* (*E.*) *miliaris diversa* (Kenyon, 1902)
Journ. Conch. **10:** 184
Localities **40, 7, 11**
Kenyon (1902): Shark Bay, West Australia

	L	W	H	lip	col
Largest shell:	40.8	25.2	20.4	22	16
Smallest shell:	33.5	23.2	17.6	19	15

Seven shells were examined. The subspecies is most common at Broome and Cable Beach; the specimens listed above were both from the latter beach. Iredale (1935) gave the name *Erosaria metavona* to the Queensland race of *E. miliaris*. Later (1939), he examined a specimen from Shark Bay and compared it with *E. metavona* but agreed it was more pinched anteriorly and more elevated than that species. He further mentioned that the Kenyon type was a dead shell and its coloration indistinguishable. It is not clear why Iredale questioned the species. Aside from the characteristic features of the shell, Mrs. Kenyon evidently was aware of what species she was working with, for she concluded her discussion with "I think the discovery of this variety (Shark Bay, West Australia) proves the complete separation of the two species *C. eburnea* and *C. miliaris*." Further, it is difficult to understand why Schilder & Schilder (1938 - 39, 1941) used, for an east Australian race whose range is from northeast Australia to Port Moresby, the name Kenyon proposed for these Dampierian shells.

The Exmouth Gulf shells are of a fairly large size, a yellow-buff dorsal coloring, thickly covered with small white spots of various sizes; both thickened upswept margins are pitted and are white, as are the base, teeth, and

interstices. The teeth are sharply pointed on the lip. A grey mantle line traverses the upper right dorsum.

Monetaria TROSCHEL, 1863
(*Ornamentaria* SCHILDER & SCHILDER, 1936)

14. *Monetaria* (*O.*) *annulus annulus* (LINNAEUS, 1758)
Syst. Nat., Ed. 10, p. 723
Localities **7, 11**
HEDLEY (1915) (*ex* MENKE, 1843) IREDALE (1935): Western Australia
SCHILDER (1941): **7, 12, 79**
ALLAN (1956): Dampierian Region

	L	W	H	lip	col
Largest shell:	25.0	16.8	12.0	13	9
Smallest shell:	21.9	15.7	10.8	13	11

Four shells were examined. It is a common species, known to range from Quobba Point to Cape Leveque, intertidally.

(*Monetaria* TROSCHEL, 1863)
15. *Monetaria* (*M.*) *moneta rhomboides* SCHILDER & SCHILDER, 1933
Zool. Meded. Leiden, **16**: 163
Localities **40, 90, 59, 7, 43**
HEDLEY (1915) (*ex* MENKE, 1843): West Australia
IREDALE (1914): **56**
SCHILDER (1941): **40, 71, 29**
ALLAN (1956): Dampierian Region
WEAVER (1960): **53**

	L	W	H	lip	col
Largest shell:	44.2	32.0	22.9	13	11
Smallest shell:	18.8	11.7	9.0	12	13

Eight shells were examined. This species is fairly common from Quobba Point to Cape Leveque. There is considerable variation in size. The color ranges from a pale yellow-grey-green almost to a deep yellow-orange. A large percentage of specimens shows a fine, bright orange dorsal ring. However, it is not, because of this, to be confused with *Monetaria annulus* (LINNAEUS, 1758), as it in no way otherwise approaches the appearance of this latter species.

Erronea TROSCHEL, 1863
(*Adusta* JOUSSEAUME, 1884)
16. *Erronea* (*A.*) *subviridis dorsalis* SCHILDER & SCHILDER, 1938
Proc. Malac. Soc. London, **23** (3): 149
Localities **40, 90, 59, 48, 7, 11, 50, 13**
HEDLEY (1915) (*ex* BRAZIER, 1879): **57, 30**
IREDALE (1939): Western Australia
SCHILDER (1941): **7, 12, 79, 40, 71, 68, 69, 22**
ALLAN (1956): Western Australia, **7**, Northern Australia

	L	W	H	lip	col
Largest shell:	36.0	22.0	17.2	19	18
Smallest shell:	22.2	13.0	10.6	19	15

Forty-two shells were examined. The species is common at all stations. IREDALE (1935) compares this Western Australian form to *Cypraea viridis* REEVE, 1835, which was described without locality. STEADMAN & COTTON (1946) did not recognize *Erronea subviridis dorsalis*, preferring to list it as *E. subviridis subviridis* (REEVE, 1835). ALLAN (1956), having seen many of the western shells, agrees with the Schilderian name. The finely punctate dorsum with its large central chestnut blotch separates this subspecies from the other two races characterized by interrupted grey dorsal zones. The Lagrange Bay shell was collected on the beach 12 miles south of Cape Bossut. The Abrolhos specimen was taken in a craypot, in from five to six fathoms, at North Island. All the shells examined in this study were collected between there and Cable Beach. This species seems equally adaptable to both intertidal and deep water habitats, down to at least 10 fathoms.

17. *Erronea* (*A.*) *pyriformis smithi* (SOWERBY, 1881)
Proc. Zool. Soc. London for **1881**: 638
Localities **17, 32, 49, 59, 5**
IREDALE (1935): West Australia
SCHILDER (1941): **7, 12, 79, 68, 69, 22**
STEADMAN & COTTON (1946): North West Australia
ALLAN (1956): **50**

	L	W	H	lip	col
Largest shell:	28.6	16.7	14.1	17	21
Smallest shell:	17.3	12.0	9.8	18	15

Seven shells were examined. The species is uncommon. The general appearance of these shells — which are noticeably small for the species — is short, wide, and abruptly pyriform; lacking on many of the shells, especially on those from Disaster Bay, is the characteristic brown interrupted dorsal color banding. The brown coloring of the teeth is usually paler, also. In so far as this short series of shells shows, it would seem that SOWERBY's *Erronea pyriformis smithi* is reasonably easily separable from the east Australian race, *E. pyriformis pyriformis* (GRAY, 1824) morphologically and geographically.

18. *Erronea* (*A.*) *walkeri continens* (IREDALE, 1935)
Austral. Zool., **8** (2): 127
Localities **7, 37, 43** to **11**
SCHILDER (1941): **22, 88**
STEADMAN & COTTON (1946): **69**
ALLAN (1956): **69**

	L	W	H	lip	col
Largest shell:	26.1	14.8	12.4	22	21
Smallest shell:	21.0	12.2	10.0	19	17

Nine shells were examined. This species is scarce although not rare in Western Australia. At Broome these mollusks were found moving across exposed, bare sand flats more than a half mile from the nearest cover. They seem to be essentially sand-dwelling cowries, not found on rocks. They are apt to occur on a muddy, sandy substrate where a sparse weed growth is present, taking cover in and under pieces of dead shell and old iron. (*Erronea subviridis dorsalis* SCHILDER & SCHILDER, 1938 is another species found out in the open in the same way.) A pair of *E. walkeri continens* was observed sharing the same half-valve of a discarded oyster shell.

(*Erronea* TROSCHEL, 1863)

19. *Erronea* (*E.*) *ovum ovum* (GMELIN, 1791)

Syst. Nat., Ed. 13, p. 3412

Locality **4**

SCHILDER (1941): **7, 12, 79**

	L	W	H	lip	col
Largest shell:	25.3	15.0	12.6	15	15
Smallest shell:	19.4	11.6	9.6	13	13

Four shells were examined. These specimens are from the B. E. Bardwell (Broome) Collection, and are said to have been collected by pearl luggers about 1922. We know of no recent occurrence of this species in Western Australia, and it therefore must be considered a rare species there. The dorsal coloring in these shells appears to be a much lighter greyish-green than is normally observed in the eastern races.

WEAVER (1960) reported collecting "*Cypraea ovum*" from Long Island at the north end of Exmouth Gulf, but these shells have subsequently been identified as *Ovula ovum* (LINNAEUS, 1758) (personal communication).

20. *Erronea* (*E.*) *errones coxi* (BRAZIER, 1872)

Proc. Zool. Soc. London, **1872: 617**

Localities **40, 90, 59, 7, 11, 68, 17**

HEDLEY (1915) (*ex* MENKE, 1843), IREDALE (1939), STEADMAN & COTTON (1946): Western Australia

SCHILDER (1941): **40** (*E. coxi*), **71, 28**

ALLAN (1956): Dampierian Region, **7**, Western Australia

WEAVER (1960): **53**

	L	W	H	lip	col
Largest shell:	35.0	19.7	15.9	18	14
Smallest shell:	29.0	16.6	13.8	15	16

Eighteen shells were examined. This is a common species in northwestern Australia. It has been the subject of some taxonomic controversy; IREDALE (1939) raised this subspecies to full specific rank, giving it the name *Erronea magerrones magerrones* and established the Dampierian form as a race, *E. magerrones proba*. They are doubtfully distinct from *E. errones errones* (LINNAEUS, 1758). The western form *E. e. coxi* is a good geographical race. The type locality is Broome.

21. *Erronea* (*E.*) *cylindrica sowerbyana* SCHILDER, 1932

Foss. Cat., Cypraeacea: 192

Localities **40, 90, 59, 60, 7, 43, 11, 68, 17**

HEDLEY (1915): **79** (*ex* BRAZIER, 1882)

IREDALE (1935), STEADMAN & COTTON (1946): North West Australia

SCHILDER (1941): **7, 12, 79, 40, 71, 28**

WEAVER (1960): **53**

ALLAN (1956): Western Australia

	L	W	H	lip	col
Largest shell:	32.8	16.7	13.9	22	23
Smallest shell:	25.0	12.9	10.8	17	18

Twenty-seven shells were examined. It is a common form at most localities. The measurements above were taken from Roebuck Bay shells; Exmouth Gulf specimens seem to average smaller.

22. *Erronea* (*E.*) *caurica blaesa* IREDALE, 1939

Austral. Zool., **9** (3): 322

Localities **40, 90, 59, 7, 11, 73, 17**

HEDLEY (1915) (*ex* MENKE, 1843): West Australia

IREDALE (1935, 1939): West Australia; (1914): **48**

SCHILDER (1941): **40, 71, 28**

STEADMAN & COTTON (1946): Northwest Australia

ALLAN (1956): **7**, West Australia

	L	W	H	lip	col
Largest shell:	46.0	25.9	20.8	20	19
Smallest shell:	36.6	20.4	16.3	16	14

Twenty-six shells were examined. This subspecies seems to be more common in that part of its range from Quobba Point to Exmouth Gulf. A collector in Broome, the type locality, reports, "you find the odd one of these alive, far more are dead on the beaches than anywhere else." The western shells are generally large for the species, and apparently of only moderately common occurrence throughout its known range, Quobba Point to Cape Leveque.

(*Guttacypraea* Iredale, 1935)

Notocypraea Schilder, 1927

23. *Notocypraea* (*G.*) *pulicaria* (Reeve, 1846)

Conch. Icon., vol. 3, *Cypraea*, fig. 84

Localities **18, 10, 45**, Southwest Australia

Hedley (1915) (*ex* Hidalgo, 1907): **45**

Iredale (1935): West Australia

Schilder (1941): **45, 42, 87**

Steadman & Cotton (1946): Western Australia

Allan (1956): Western Australia, **52**

	L	W	H	lip	col
Largest shell:	21.0	11.6	9.0	28	27
Smallest shell:	16.2	9.5	7.4	22	21

Twelve shells were examined. This species is uncommon to rare, and although occasionally collected intertidally, it is more commonly dredged from deeper water. The range seems to extend southward from the area of Swan River in the west to Eucla in South Australia.

Palmadusta Iredale, 1930

(*Palmadusta* Iredale, 1930)

24. *Palmadusta* (*P.*) *asellus asellus* (Linnaeus, 1758)

Syst. Nat., Ed. 10, p. 722

Localities **40, 90, 59, 65, 61, 7**

Cotton (1950): North West Australia (B. E. Bardwell, Broome)

Allan (1956): repeats Cotton, 1950

	L	W	H	lip	col
Largest shell:	18.3	11.1	8.5	19	13
Smallest shell:	17.0	10.5	8.5	16	15

Three shells were examined, one subadult. Two were collected at Broome, the third off Old Onslow Beach. Specimens from the other localities listed are in the Whitworth Collection or have, from time to time, been observed in subfossil form in beachdrift. The three above mentioned shells were all collected by Mr. Bardwell. One was received directly from him, the other two from the collection of R. Sharon, Redondo Beach, California. There seems little doubt the species is rare and obviously needs further investigation.

25. *Palmadusta* (*P.*) *clandestina clandestina* (Linnaeus, 1767)

Syst. Nat., Ed. 12, p. 1177

Localities **90, 59, 40, 77, 49, 17**

Allan (1956): **7**

Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	23.0	13.7	11.0	21	16
Smallest shell:	14.8	9.6	7.7	18	15

Twenty-one shells were examined. The species is common and ranges from Quobba Point to Cape Leveque. Some authors place this group with the subspecies *Palmadusta clandestina moniliaris* (Lamarck, 1810); however, it seems to be more closely allied with the nominate subspecies from Ceylon. The Exmouth Gulf shells are often large in size, comparing favorably with the east African *P. clandestina passerina* (Melvill, 1888) in this respect.

26. *Palmadusta* (*P.*) *saulae saulae* (Gaskoin, 1843)

Proc. Zool. Soc. London for **1843**: 23

Locality **7**

	L	W	H	lip	col
Shell measurements:	26.0	15.2	11.7	22	17

One shell examined; very rare.

This specimen was collected alive by Mr. Ted Crake, Broome, and is possibly the first example of this species reported from Western Australia. Because it is apparently a unique specimen with an unusual locality record, it seems to deserve special mention here. It differs somewhat in outward appearance from *Palmadusta saulae saulae* (Gaskoin) from the Philippines, and even its most closely related race, *P. saulae nugata* Iredale, 1935, is markedly different.

The Dampierian shell is large and broad, narrowing quickly abapically. At best it seems to relate more favorably with the northern (Gaskoin) race (L 26.8; W 14.9; H 12.3; lip 20; col. 17; Cate Coll. 1048; see Cate, 1960). It is bulbously ovate, umbilicate; teeth are short, well defined on the outer lip, intermittently so on the columella but extending across the fossula. The front and rear terminals are noticeably rostrate; the right margin is thick, the left side is uncallused and curves smoothly from dorsum to base; the primary shell color is pearl-grey, with a very large central brown dorsal blotch that covers at least 20 per cent of the upper surface; the remaining area is thickly sprinkled with minute brown dots, the margins are copiously flecked with larger brown spots, and in addition there is a brown spire blotch. For the most part the base is devoid of spots, is of a lighter basic grey color, as are the teeth. The terminal openings, columella, fossula, and interstices are bright orange-yellow. The animal's foot and mantle are brilliant orange, marked with fawn-colored spots.

The animal was collected in mid-December 1962 and was found high up in a very small tide pool filled with about four feet of water during a neap tide. Mr. Crake relates, "There was one rock I could turn in the pool, and it was quite small. Underneath was a beautiful *Cypraea fallax* and right along side was the *C. saulae,* both with mantles up."

27. *Palmadusta* (*P.*) *lutea bizonata* Iredale, 1935

Austral. Zool., 8 (2): 126

Cypraea lutea Gmelin, 1791

Syst. Nat., Ed. 13, p. 3414

(*non C. lutea* Gronovius, 1781 of authors[non binominal])

Zoophyl. Gronoviani, 3: 287, pl. 19, fig. 17

Localities **90, 59, 40, 43, 17, 7**

Hedley (1915): **57** (*ex* Brazier, 1872)

Iredale (1935): North West Australia (**57**)

Schilder (1941): **81, 21, 46, 40, 71, 28**

	L	W	H	lip	col
Largest shell:	17.5	10.1	8.3	19	17
Smallest shell:	15.5	9.7	8.3	17	17

Three shells were examined. The species is uncommon. The report from Broome is that only an occasional shell is ever found, which is true for the other stations as well.

28. *Palmadusta* (*P.*) *ziczac ziczac* (Linnaeus, 1758)

Syst. Nat., Ed. 10, p. 722

Localities: **90, 59, 66**

Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	19.0	10.5	8.3	19	20
Smallest shell:	13.8	9.0	7.1	18	16

Nine shells were examined. The species is uncommon. All shells were collected dead in the beach drift. Though beach-rolled, the shell color and markings were well preserved. The Vlaming Head shells appear to be narrower, somewhat longer than the shells of the other races, and to have a narrower, straighter ventral aperture.

(*Melicerona* Iredale, 1930)

29. *Palmadusta* (*M.*) *gracilis hilda* (Iredale, 1939)

Austral. Zool., 9 (3): 312

Localities **21, 40, 7**

Schilder (1941): **81, 46, 21, 68, 69, 22**

Steadman & Cotton (1946): **81**

Cotton (1950): **77** (B. E. Bardwell)

Allan (1956): **81, 77**

	L	W	H	lip	col
Largest shell:	16.4	10.4	8.3	17	13
Smallest shell:	14.0	9.7	7.6	13	14

Twenty-three shells were examined. At Broome, only an occasional living specimen is collected; however, many dead shells can be picked up on the beach in the proximity of Lighthouse Point. The species is fairly common and ranges from Shark Bay to Cape Leveque. Schilder & Schilder (1938-39) taxonomically combined these western shells with the southeast Australian (Botany Bay) *Palmadusta gracilis macula* (Angas, 1867) but did not speculate that they might be racially distinct. Iredale (1939) separated them but elevated *P. macula* to full specific status, considering this Dampierian form new to science. Believing that *P. macula* did not belong in the subgenus *Melicerona* Iredale, 1930, he established a new subgenus, *Cupinota*, with *P. macula* as its type. After comparing series of *P. macula* with similar series of *P. gracilis gracilis* (Gaskoin, 1849) I consider it unnecessary to make this taxonomic change; therefore I have retained the combination *Palmadusta* (*Melicerona*) *gracilis hilda* (Iredale, 1939), the type locality of which is Shark Bay.

30. *Palmadusta* (*M.*) *fimbriata fimbriata* (Gmelin, 1791)

Syst. Nat., Ed. 13, p. 3420

Localities **90, 59, 40, 57, 5**

Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	11.4	6.6	5.2	15	16
Smallest shell:	10.8	6.5	5.1	16	16

Three shells were examined. The species is uncommon. The shells studied were collected approximately midway between Vlaming Head and Point Murat. Other specimens are known to have been collected deeper in the recesses of Exmouth Gulf. Shells from Nickol Bay and Beagle Bay are in the Whitworth Collection (Geraldton).

31. *Palmadusta* (*M.*) *hammondae* (Iredale, 1939)

Austral. Zool., 9 (3): 312; plt. 28, figs. 19 - 22

Localities **75, 7**

Steadman & Cotton (1946): Clarence River, N. S. W.

Iredale (1939): Yirrkala, Northern Territory; Woolgoola, N. S. W.

Allan (1956): Type locality, Clarence River Heads, N. S. W.

	L	W	H	lip	col
Largest shell:	16.6	9.6	8.0	16	16
Smallest shell:	14.0	7.7	6.2	16	15

Five shells were examined, four from Broome, Roebuck Bay and one from Stradbroke Island, Moreton Bay, south-eastern Queensland. This is a relatively new species, closely related to the *Palmadusta fimbriata* complex of allopatric races, having, among other similar characteristics, the pale lavender terminals common to this group. As far as we know at the present time the species is uncommon and apparently occupies an unusually wide range. The type locality is given as Clarence River Heads, Northern New South Wales.

(*Blasicrura* IREDALE, 1930)

32. *Blasicrura* (*B.*) *quadrimaculata thielei* SCHILDER & SCHILDER, 1938

Proc. Malac. Soc. London, 23 (3): 164

Localities **43, 86, 7, 17, 72, 89**

SCHILDER (1941): **7, 12, 79**

COTTON (1950): **77** (B. E. Bardwell, Broome)

ALLAN (1956): **7**

	L	W	H	lip	col
Largest shell:	23.0	13.0	11.2	17	17
Smallest shell:	18.8	10.9	8.9	18	15

Ten shells were examined, eight from Sunday Island, King Sound and two from Gantheaume Point, Roebuck Bay. The northern shells are larger and more greenish. The Gantheaume Point shells are both about equal in size, smaller than the others and with paler greyish dorsal color. The species is not common, apparently not ranging much farther south than Broome; it occurs more frequently from Price's Point to Troughton Island in the north.

33. *Blasicrura* (*B.*) *pallidula simulans* SCHILDER & SCHILDER, 1940

Arch. Molluskenkunde **72**: 42

Localities **90, 59, 37, 7, 73, 73** to **7**

SCHILDER (1941): **46, 81, 21**

ALLAN (1956): Western Australia (= *fluctuans* IREDALE, 1935)

	L	W	H	lip	col
Largest shell:	20.9	11.2	9.1	22	17
Smallest shell:	16.4	9.2	7.2	19	17

Eleven shells were examined. Fairly common, though SCHILDER & SCHILDER (1952) recorded these shells as rare. I have compared specimens with the form *Blasicrura pallidula rhinoceros* (SOUVERBIE, 1865) from Gubbins Reef, Cooktown, northern Queensland, and they display a reasonably pronounced morphic variation, having the terminals more produced, longer and more distinct teeth, a more pyriform shape and distinctly interrupted dorsal color bands. The western shells seem also to average larger in size. "*Blasicrura interrupta* (GRAY, 1824)" of authors for this locality probably refers to subadult examples of *B. pallidula*, as no evidence has yet been found to suggest the presence in this region of *B. interrupta*. While this species is also found on rocks at low tide, it seems to show some preference for sheltered tide pools higher up inshore.

(*Derstolida* IREDALE, 1935)

34. *Blasicrura* (*D.*) *hirundo cameroni* IREDALE, 1939

Austral. Zool., **9** (3): 314; plt. 28, figs. 29 - 31

Localities **90, 59, 40, 7**

IREDALE (1939): **81**, Yirrkala, Northern Territory

SCHILDER (1941): North West Australia

STEADMAN & COTTON (1946): North Australia

WEAVER (1960): **53**

	L	W	H	lip	col
Largest shell:	20.4	14.0	10.8	21	17
Smallest shell:	12.4	7.6	6.1	18	14

Seventeen shells were examined. The species is common at Vlaming Head and Exmouth Gulf, but a report from Broome (Crake) says the shells are not common there, "just the odd shell now and then." These grey-topped shells may possess a small central blotch. Two white lines cross the blue-grey dorsum transversely, the anterior one looking roughly like the numeral 2 lying on its side, whereas the adapical line is straight. This pattern appears to be constant for the species. There are prominent brown blotches on either side of the front and rear terminals, with finer brown spotting along the margins. Otherwise the terminals, margins, base, teeth, and interstices are white. There is an interesting variation in the columellar dentition: on nearly half of the specimens the columellar teeth are very short, becoming obsolete on the front half of the base, while on the others the central teeth are long -- nearly reaching the marginal edge -- and well defined the full length of the base. In each case the teeth are strong on the fossula. In this race of *Blasicrura hirundo* (LINNAEUS, 1758), the shells are larger and bulbously broader; the dorsal markings also are correspondingly larger and more prominent.

Working with these shells from both Exmouth Gulf and Broome, I have observed what appears to be a distinct dimensional separation in the species. The larger shells (20.4, 14.0, 10.8, 21, 20) and the smaller shells (14.8, 9.0, 7.1, 18, 17) are found living together even though they seem to possess rather uniform shell and color characteristics. Even so, the dwarf specimens seem to approach more closely *C. hirundo neglecta* SOWERBY, 1837, while the larger ones are unquestionably the *C. hirundo cameroni* of IREDALE.

35. *Blasicrura* (*D.*) *ursellus ursellus* (GMELIN, 1791)

Syst. Nat., Ed. 13, p. 3411

Locality **7**

	L	W	H	lip	col
Largest shell:	13.0	8.2	6.5	18	18
Smallest shell:	9.2	5.7	4.6	17	17

Seven shells were examined, all of which were collected at Broome (*ex* Colls. Bardwell - 1; V. M. Baker - 1; C. N. Cate - 5). All were dead beach specimens though in excellent condition. The occurrence of this species at this locality is rare, and it is not known in our experience from elsewhere in northwest Australia. IREDALE (1939) appears to have confused this species with *Blasicrura hirundo* (LINNAEUS, 1758) *Blasicrura ursellus* is unquestionably a distinct species that can very easily be separated by a

distinctive lavender-grey dorsal pattern characteristic of and constant in all examples, and by the unusual way the columellar and labral teeth merge in the vicinity of the adapical terminal collar; neither *B. hirundo* nor *B. kieneri* have this unusual arrangement of teeth. In *Blasicrura ursellus* the shells are usually smaller and more pyriform, never displaying the brown dorsal blotch common to the other species.

36. *Blasicrura* (*D.*) *stolida stolida* (Linnaeus, 1758)
Syst. Nat., Ed. 10: 724
Localities **90, 59**
Cotton (1950): **7** (*leg.* R. W. Tymms, list B. E. Bardwell)
Allan (1956): **7, 77**

	L	W	H	lip	col
Largest shell:	28.4	16.1	13.1	23	20
Smallest shell:	27.0	15.6	12.7	22	19

Two shells were examined. This is an uncommon species, apparently isolated in West Australia from Vlaming Head to Broome. Curiously, it shares a part of its range with *Blasicrura stolida brevidentata* (Sowerby, 1870). On available evidence there does not appear to be any hybridization between the two subpecies. Our knowledge of this form in West Australia is limited to the single locality given, with this field note, "Found two *C. stolida stolida,* one in fair shape, the other has lost some dorsal colouring, but is otherwise intact. Only know of two other specimens found at North West Cape Light, one by each of the lightkeepers' wives."

37. *Blasicrura* (*D.*) *stolida brevidentata* (Sowerby, 1870)
Thes. Conch., 4 (30): 11; plt. 30, figs. 325 - 326
Localities **66a, 19, 7, 11, 77**
Hedley (1915): **18** (*ex* Cox, 1900 = *irvinae*)
Schilder (1941): **7, 12, 11, 77, 79**
Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	24.8	15.0	11.5	15	13
Smallest shell:	20.4	12.3	10.3	16	12

Ten shells were examined. This race is fairly common. The two shells whose measurements are listed above were collected at Broome, Roebuck Bay. Cotton (1950) and Allan (1956) recognize *Blasicrura stolida stolida* (Linnaeus) from northwest Australia, but with Iredale (1939) seem not to know of this subspecies living there as well. One wonders if in fact they were not referring to the Sowerby subspecies, since the Linnaean one has only recently been found in Western Australia. The type locality of *B. s. brevidentata* is Broome. I have specimens from Thursday Island, Torres Strait, that apparently link the former with Western Australia. The two races are easy to separate through differences in general color patterns, shape of shell, and character of base teeth.

Cribraria Jousseaume, 1884
(*Talostolida* Iredale, 1931)

38. *Cribraria* (*T.*) *teres teres* (Gmelin, 1791)
Syst. Nat., Ed. 13, p. 3405
syn.: *Cypraea tabescens* Dillwyn, 1817
Localities **90, 59, 40**
Iredale (1935): West Australia (Hedley, Thiele)
Schilder (1941): North West Australia
Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	33.5	19.1	15.7	25	27
Smallest shell:	21.2	12.2	9.3	22	24

Nineteen shells were examined. Within an apparently restricted range, the species is common. Iredale (1935) stated that Hedley recorded a shell from West Australia under the name of *Cribraria teres,* but "fortunately" the shell proved to be a dead *Erronea caurica.* He added that Thiele recorded the species from the same western area. From Vlaming Head to Point Murat in Exmouth Gulf, dead shells are quite numerous on the beaches. As far as can be determined, it does not reach Roebuck Bay to the north nor Shark Bay to the south.

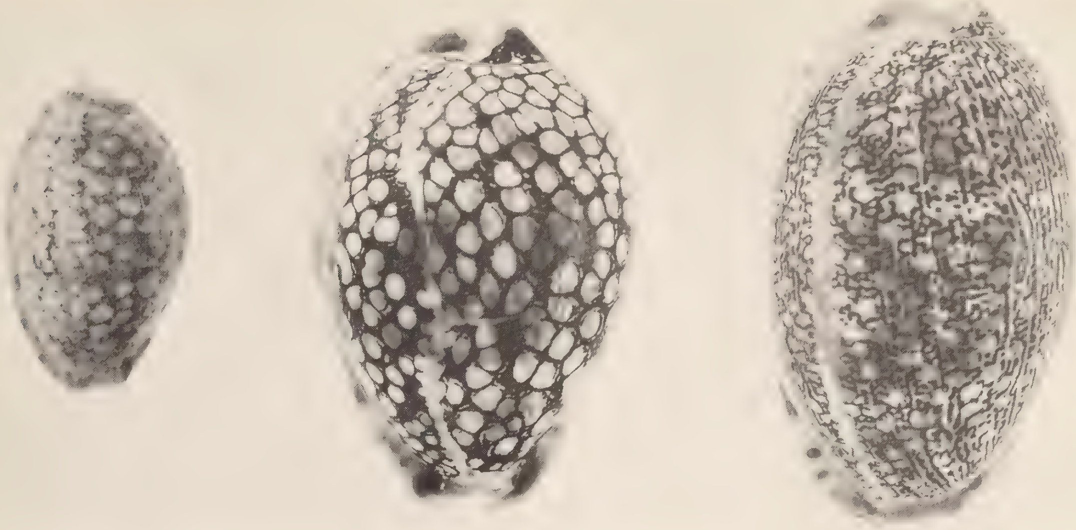
(*Ovatipsa* Iredale, 1931)

39. ***Cribraria* (*Ovatipsa*) *chinensis whitworthi*** Cate, subspec. nov.
Localities **90, 59, 40, 53**
Cotton (1935): N. W. Australia (as *Cypraea variolaria*)
Schilder (1941): North West Australia (as *O. chinensis sydneyensis*); **12, 7, 79**
Weaver (1960): **53** (as *C. chinensis chinensis*)

	L	W	H	lip	col
Largest shell:	40.7	24.4	20.2	17	15
Smallest shell:	24.2	14.7	12.0	16	13

Seventeen specimens were examined. The species is evidently reasonably common only at Vlaming Head. It is a deep water form, requiring a violent surf action to bring the shells in on the beach. We know of no live collected shells; three have been obtained with the dead animal in the shell and the others are dead beach shells in various states of preservation. The species has been collected only from the very restricted area directly below the lighthouse (five miles west and slightly south of the tip of North West Cape) where it washes up on the beach across a narrow shelf of rock that is seldom uncovered by the tide.

This species was recorded by Cotton (1950) as *Ovatipsa chinensis variolaria* (Lamarck) in the B. E. Bardwell Collection, from North West Australia. Schilder (1941) also recorded it, as *Ovatipsa chinensis sydneyensis,* from this general area. A definite report can now be made



2 1
Figure 1 a Figure 2 a Figure 3 a

Figure 1 b Figure 2 b Figure 3 b
2 1

Figures 1 a, 1 b: *Arabica histrio westralis* IREDALE, 1935 *ex* C. N. Cate Coll., No. 2165; Hypotype 1 (natural size). Figures 2 a, 2 b: *Ovatipsa chinensis whitworthi* CATE, subspec. nov. *ex* C. N. Cate Coll., 2180; Holotype (natural size). Figures 3 a, 3 b: *Arabica arabica brunnescens* CATE, subspec. nov. *ex* C. N. Cate Coll., No. 2164; Holotype (natural size).

photography: TAKEO SUSUKI

for this subspecies as living at the above-listed stations.

Description:

The shell is generally large, solid, pyriformly elongate, narrowing perceptibly abapically, then abruptly to the anterior terminals; it becomes rounded and blunt adapically; base bulbously swollen; left side thickened, rounded; right margin thickened, calloused, sharply angled, keeled; aperture reasonably straight, wide, curving gradually left to the rear; front terminal barely produced, not at all adapically, semi-umbilicate above; outer lip broad, labial teeth large, heavy, well defined, long, evenly spaced; columella curving, teeth fine, very short; fossula narrow, shallow, only slightly concave, ribbed with teeth, faint to the rear, heavy anteriorly; terminal ridge well defined, curving slightly to the right; dorsal inductura glossy, light brownish-yellow, thickly patterned with variously sized beige-grey lacunae; thick, broad, beige-colored lateral callus sweeping high on either side, generally covering much of the dorsum; the sides and most of the base very thickly spotted with large, bright lavender spots; a weak, sometimes indistinct mantle line traversing the upper right dorsal surface; minimal base area and teeth a rich beige, the interstices brilliant orange.

Type locality:

The type locality is Vlaming Head (21°48′ S. Lat., 114°07′ E. Long.), North West Cape; the holotype will be deposited in the type collection at the Western Australian Museum, Perth, and will bear the catalog number W. A. M. 33-64.

In *Cribraria chinensis whitworthi* the shell is normally large, approaching the form of the east African *C. chinensis violacea* Rous, 1905. The West Australian shell is more heavily constructed. The long, shallow, narrow, heavily ribbed fossula is a consistent differentiating character in *C. c. whitworthi*. Perhaps the most outstanding feature of this new race is its brilliant lavender color and the size and density of the lateral spotting.

This species is named in honor of Mr. A. R. Whitworth of Geraldton, Western Australia, for his various contributions to our knowledge of the *Cypraea* living in the Dampierian Region.

Ovatipsa chinensis sydneyensis Schilder & Schilder, 1938, and *O. c. variolaria* (Lamarck, 1810) are geographically remote and of different form. *Cypraea sydneyensis* is a narrower, more ovate shell, while that of *C. variolaria* is much larger and of lighter, less solid construction.

(*Cribraria* Jousseaume, 1884)

40. *Cribraria* (*C.*) *cribraria fallax* (E. A. Smith, 1881)

Ann. Mag. Nat. Hist., ser. 5, **8**: 441

syn.: *Cypraea exmouthensis* Melvill, 1888

Localities **90, 59, 40, 7, 43, 77, 31, 50**

Hedley (1915): West Australia (*ex* E. A. Smith, 1881)

Iredale (1935): **40**, Western Australia (T. H. Haynes =*exmouthensis*), West Australia (*ex* E. A. Smith, 1881)

Schilder (1941): North West Australia

Steadman & Cotton (1946): **40**, West Australia

Allan (1956): **40**, Dampierian to Flindersian Regions

Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	34.5	22.0	17.6	19	20
Smallest shell:	16.7	10.2	8.1	17	14

Twenty-one shells were examined. This subspecies is fairly common within the range from Dirk Hartog Island to Gantheaume Point. Iredale (1935) and Steadman & Cotton (1946) were of the opinion that *Cribraria fallax* and *C. exmouthensis* were separate races living together. It seems unlikely that racial distinction can be maintained with the species intermingling as freely as they seem to do. *Cribraria exmouthensis* was established on the basis of size, color, and lacunae -- characters that are commonly observed in series of the shells. Melvill's (1888) remarks seem to add further uncertainty respecting this subspecies when he states "The dorsal covering matter seems to have been twice deposited, causing a very rich effect, with partial eclipse of the round white spots." Additionally, he suggests the smaller size of the shell (up to one inch) and more sparsely arranged white spots as differentiating characters. It might be added that some of the shells have a white dorsum devoid of any spotting. In my opinion, the earlier name *C. fallax* is the proper one for these shells.

Three large specimens, gathered by deep water divers, were brought in by pearling luggers from Lagrange Bay. These shells show the deep coloring mentioned by Melvill, as well as the fewer white spots, but again this is not uncommon in any series of shells, particularly with the larger specimens found in any of these western shell colonies. One dead shell was dredged in from 80 to 85 fathoms off the north end of Dirk Hartog Island (Weaver, 1960). This is one of several species of Cypraeidae in Western Australia that seems to thrive in either shallow or deep water.

Cypraeinae

Bernaya Jousseaume, 1884

41. *Bernaya catei* Schilder, 1963

The Veliger **5** (4): 127

Locality **92**

	L	W	H	lip	col
Shell measurements:	75.7	49.4	39.8	23	17

A unique specimen was examined. The holotype (Cate Coll. C 563) was found after a storm by a crayfisherman in the spring of 1961. It was on the beach of the western shore of West Wallaby Island and still contained the fresh dead animal. SCHILDER (1963) disqualified it as *Cypraea venusta* SOWERBY, 1846 (CATE, 1962), and compared it with *Bernaya media* (DESHAYES, 1835), *B. cavata* (EDWARDS, 1865), *B. baluchistanensis* (NOETLING, 1897), and *B. brevis* (DOUVILLÉ, 1920), all from the Eocene of France and England, Upper Cretaceous of Pakistan and Libya, and Eocene of Nigeria, respectively.

(see *Zoila venusta venusta* SOWERBY, 1846 below)

Zoila JOUSSEAUME, 1884

42. *Zoila venusta venusta* (SOWERBY, 1846)

Proc. Linn. Soc. London, pt. 1: 314

Synonyms:

Cypraea thatcheri COX, 1869
C. roseopunctata MELVILL, 1888
C. Brunea COX, 1889
C. venusta var. *brunea* [COX] HIDALGO, 1906
C. venusta var. *bakeri* GATLIFF, 1916
C. episema IREDALE, 1939

Localities **45, 18, 33**

SOWERBY (1846): locality unknown
COX (1869): **28**
MELVILL (1888): **29**
COX (1889): **18**
HEDLEY (1915) (*ex* COX, 1869): **28**
GATLIFF (1916): locality unknown
IREDALE (1939): **18**
SCHILDER (1941): **28**

	L	W	H	lip	col
Largest shell:	80.9	49.5	43.1	24	9
Smallest shell:	74.6	49.5	40.3	27	8

Six shells were examined. This species is a deep water form and is uncommon to rare. The point of origin and center of concentration probably is southern Geographe Bay, and the range may or may not be continuous to Sorrento Reef, offshore just north of Perth; beyond this there is a reasonably abundant deep water variant (in from 15 to 70 feet). (see *Zoila venusta sorrentensis* SCHILDER, 1963 - next taxon)

Two typically formed *Zoila venusta,* though smaller in size (67.2 mm and 69.0 mm in length, respectively) and more or less identical with the Geographe Bay shells, were collected in 65 feet of water off Binningup Beach, approximately 70 miles south of Perth. There is no morphological evidence of these shells merging into the more northern *Z. sorrentensis* SCHILDER.

43. *Zoila venusta sorrentensis* SCHILDER, 1963

The Veliger **5** (4): 126; *ibid.* (1): plt. 3, figs. 1 - 3, and text fig. 2

Localities **82, ?48**

	L	W	H	lip	col
Largest shell:	60.9	40.1	32.9	26	11
Smallest shell:	53.0	34.6	27.8	23	10

Eight shells were examined. This new subspecies has been rather intensively collected in from 10 to 40 feet of water at Sorrento Reef, just north of Perth. It would probably be incorrect to say the shell was of common occurrence; however, many specimens are known to have been collected here with the aid of SCUBA diving equipment. It has heretofore been considered a variant of *Zoila episema* IREDALE, 1939 (see CATE, 1962). SCHILDER subsequently designated it as a race of *Z. venusta.* A dead beach specimen has been reported from the Abrolhos Islands. This locality record will need verification through additional field work.

44. *Zoila episema* IREDALE, 1939

Austral. Zool., **9** (3): 300; plt. 27, figs. 3 - 4

see *Zoila venusta venusta* (SOWERBY, 1846) above

45. *Zoila decipiens* (E. A. SMITH, 1880)

Proc. Zool. Soc. London for **1880:** 482; plt. 48, fig. 8

Localities **7, 47, 80, 50, 70, 43**

HEDLEY (1915): **71** (*ex* E. A. SMITH, 1880)
IREDALE (1935): West Australia
SCHILDER (1941): **7, 12, 79, 40, 71, 28**
STEADMAN & COTTON (1946): Northwest Australia
ALLAN (1956): North-Western Australia

	L	W	H	lip	col
Largest shell:	60.1	40.5	36.0	23	18
Smallest shell:	50.9	34.0	31.5	22	17

Twenty-three shells were examined. This is a common deep water species, collected mostly by pearl divers. Dead shells are very seldom found washed up on the beaches. A Japanese diver has mentioned finding four black specimens among 500 *Zoila decipiens* he collected during one season of diving.

46. *Zoila rosselli* COTTON, 1948

Trans. Roy. Soc. S. Austral., **72** (1): 30; plt. 1

Localities **42, 78, 46, 9**

ALLAN (1956): **42, 26**

	L	W	H	lip	col
Shell measurements:	58.3	38.6	27.9	31	26

One shell examined (Cate Coll. no. 1351) This specimen is one of Mr. Rossell's six original paratypes. The

type lot was collected in 1916 from dredged rubble adjacent to the North Wharf (Leighton Beach), Fremantle. The holotype is on deposit in the South Australian Museum, Adelaide (Cat. no. D 14220).

In March 1962, Max Shaw, with the aid of an aqua lung, descended 220 feet to the ocean bottom in the vicinity of Rottnest Island near Perth to collect what is probably the first live specimen known. It was living on fan coral. This species has also more recently been collected alive in Geraldton Harbor (Max Cramer Coll.). This would indicate a new northern range extension for *Zoila rosselli*. Barry Wilson (personal communication) reported three live-taken shells collected at 35 fathoms, presumably off Perth; two of these are now in the collection of the Western Australian Museum.

47. *Zoila friendii friendii* (Gray, 1831)
Zool. Misc., **1:** 35
syn.: *Cypraea scottii* Broderip, 1831
Localities **55, 45, 24, 10, 87, 42, 20, 44, 78**
Hedley (1915): **87** (*ex* Reeve, 1845)
Iredale (1935): **87**
Schilder (1941): **45, 42, 87**
Steadman & Cotton (1946): **87** (= *scottii* Broderip, 1832 [*sic*])
Weaver (1960): **44, 78**

	L	W	H	lip	col
Largest shell:	86.6	44.2	33.3	26	7
Smallest shell:	45.6	26.5	21.3	19	4

Seventeen shells were examined. This species is fairly uncommon in collections because of its deep water habitat. The shell is long and narrow, broadening gradually to the rear, where it narrows abruptly to the adapical terminal collar. The greyish-brown dorsum is densely covered with variously sized large, blurred brown spots; sides, margins, base and interstices are dark brown; teeth, fossula, columella and inner terminal walls are white. The terminals are prominently produced, posteriorly sharp-edged; the morphological features of the aperture are weakly developed and incomplete, particularly the columellar teeth and simple fossula.

The species is rather widely distributed from Perth south to Albany. Specimens have been collected at Clifton's Main Reef in Geographe Bay at five fathoms on sand and shale bottom, living on soft orange-yellow sponge; at Clifton's Reef, Outer Knob, in $2\frac{1}{2}$ fathoms at edge of reef on a patch of purple limestone; at Ludlow Beach in five fathoms on limestone reef two specimens were taken, one attached to the ceiling, another on the sandy floor under the ledge of a crayfish tunnel; others were collected in Cockburn Bay between Fremantle and Garden Island, in 25 feet of water on yellowish-brown sponge growing on mussel-encrusted pilings to which submarine nets had been attached during the last war. The water temperature at this station was between 63° and 64° F. Eleven shells were collected within an hour. (*ex* diary, C. S. Weaver)

48. *Zoila friendii vercoi* Schilder, 1930
Zool. Anzeiger, **1930: 74**
Locality **2**
Iredale (1935): West Australia; South Australia
Schilder (1941): **38, 2**
Steadman & Cotton (1946): **38**
Allan (1956): Western Australia

	L	W	H	lip	col
Shell measurements:	83.3	53.1	39.0	26	10

Two shells were examined. The specimen measured (Cate Coll. C 1706) is typical of the subspecies. The morphological difference that separates this race from the nominate *Zoila friendii friendii* is that the shells, on the average, appear larger and flatter, with greater shell width a significant feature of the shell's morphic change (63% of the length in this instance). Also, the terminals are stubbier, the coloring is less intense and more diffuse. The holotype (D969) and two paratypes are in the South Australian Museum. Three specimens are reported to be in the H. Rossell Collection (Cotton, 1950).

49. *Zoila marginata* (Gaskoin, 1849)
Proc. Zool. Soc. London for **1848:** 91
Localities **63, 48, 92, 76, 51**

	L	W	H	lip	col
Hypotype 1:	47.5	29.1	23.5	27	18
Hypotype 2:	53.9	31.5	26.1	28	21
Hypotype 3:	54.0	31.4	25.2	27	24

Three shells were examined (Cate Coll. C 906, C 2516, and T. Bratcher Coll., 2215). Hypotype 1 has been previously recorded (Cate, 1961). Hypotype 2, a live-collected specimen was found in a craypot set by the motor vessel IRIS in 30 fathoms at Houtman Rocks. It is a mature, fully developed shell, while Hypotype 1, though well formed, is subadult. This latter specimen was used to establish a type locality for the species at Albany, southwest Australia (Cate, 1961). It appears now that the locality data for that shell are questionable. Verified subsequent collections of the species clearly show the Houtman Abrolhos Islands as the true locality; I therefore correct the type locality of *Zoila marginata* to Pelsart Island, Houtman Abrolhos Group.

Until 1961 little seemed to be known about this rare species, but in the last two years a number of specimens have been taken in craypots in various localities such as in 40 fathoms off Snag Island, 100 miles south of Geraldton (*leg.* Edward Nickels); Lancelin Island; 28 fathoms, 7 or 8 miles south of Long Island, southern group, Abrolhos

Islands (T. Bratcher Coll. 2215); and Max Cramer of Geraldton has had at least five live-collected shells — so that what once was an obscure species seems to be well substantiated now.

Luria Jousseaume, 1884

(*Basilitrona* Iredale, 1930)

50. *Luria* (*B.*) *isabella rumphii* Schilder & Schilder, 1938

Proc. Malac. Soc. London, **23** (3 - 4): 177

Localities **90, 59, 40, 73** to **60**

Hedley (1915) (*ex* Menke, 1843), Iredale (1935), Allan (1956): Western Australia

Schilder (1941): North West Australia

Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	26.2	14.7	12.2	32	24
Smallest shell:	20.0	11.1	8.9	21	16

Five shells were examined. The species is not common. Not much is yet known of this group except that the shells seem to be smaller than the average for the typical species.

Talparia Troschel, 1863

(*Arestorides* Iredale, 1930)

51. *Talparia* (*A.*) *argus argus* (Linnaeus, 1758)

Syst. Nat., Ed. 10, p. 719

Localities **90, 65, 73, 59, 40**

Schilder (1941): **7, 12, 79**

	L	W	H	lip	col
Largest shell:	61.8	32.7	25.3	39	36
Smallest shell:	59.2	29.3	23.0	37	36+
				[immature]	3

Three shells were examined. The species is fairly rare. One specimen was washed up on the shore, freshly dead. Two others were collected as semi-worn beach specimens between Vlaming Head and Point Murat, Exmouth Gulf. The broken fragment of a fourth shell was observed at Vlaming Head half buried in the sand but was not collected. If the size of these specimens is any criterion for the west coast of Australia, they are small for the species when compared, for example, with the northeast Australian shells from Thursday Island (L 90.5, W 48.6, H 38.1, lip 47, col 39).

(*Talparia* Troschel, 1863)

52. *Talparia* (*T.*) *talpa talpa* (Linnaeus, 1758)

Syst. Nat., Ed. 10, p. 720

Localities **90, 59, 40, 65**

Cotton (1950): Fort George, Western Australia (B. E. Bardwell)

Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	76.5	42.4	39.1	44	45
Smallest shell:	59.5	33.4	27.5	43	44

Three shells were examined. The species is uncommon. The third shell in this series is a large bulla specimen (L 71.3, W 39.6, H 32.3, lip 44, col 44) conveying the impression that the shells in Western Australia are generally large, comparing favorably with the northern races. The living range is not yet fully determined for this species.

Mauritia Troschel, 1863

(*Arabica* Jousseaume, 1884)

53. *Mauritia* (*A.*) *eglantina perconfusa* Iredale, 1935

Austral. Zool., **8** (2): 108

ibid. **9**: plt. 18, figs. 1 - 2

Localities **7, 77, 11, 40**

Iredale (1935), Steadman & Cotton (1946): West Australia

Schilder (1941): **40, 71, 28**

	L	W	H	lip	col
Largest shell:	67.0	40.0	33.7	39	32
Smallest shell:	57.4	34.3	27.2	36	31

Ten shells were examined. The species is fairly common. Some authors have included these Western Australian shells with those of the eastern race *Mauritia* (*Arabica*) *eglantina coutourieri* (Vayssière, 1905). Though there may be merit in this approach, I consider that the Dampierian shells exhibit a peculiar endemism that is common to many West Australian species. For this and other minor morphic reasons, I am retaining the Iredale name for this race of *M. eglantina*. Vayssière's *A. coutourieri* seems reasonably restricted to an already very extensive range from Japan through southeastern Malaysia, and into Java and New Britain. *Mauritia* (*A.*) *perconfusa* on an average appears to be a larger form; the teeth are continuous on either side along a straight, narrow aperture; the margins and base are a darker, smoky, rose-beige color; the mantle line is noticeably broader and more distinct than that seen in the northern races. These larger shells, proportionately, have a greater number of labial and columellar teeth. I have been unable to find that Iredale indicated the type locality and will therefore designate Broome, Roebuck Bay (17°59′ S. Lat., 122°14′ E. Long.) as such.

54. ***Mauritia* (*Arabica*) *arabica brunnescens*** **Cate, subspec. nov.**

Synonyms:

Arabica westralis Iredale, 1935, p. 108

Mauritia (*Arabica*) *westralis,* Schilder & Schilder, 1941, p. 85

Localities **7, 77, 11, 90, 59, 40, 73** to **72**

HEDLEY (1915) (*ex* MENKE, 1843), IREDALE (1935), STEADMAN & COTTON (1946): Western Australia

SCHILDER (1941): **7, 12, 79**

ALLAN (1956): Western Australia

WEAVER (1960): **53**

	L	W	H	lip	col
Largest shell:	69.1	41.2	32.6	30	23
Smallest shell:	54.8	35.2	28.7	28	24

Seventeen shells were examined. This subspecies has been found to be common in Roebuck Bay. At present, however, little is known of its range north of Price's Point, but south to Quobba Point the species seems to be fairly well established. IREDALE (1935), in naming the northwest Australian form of *Arabica histrio* GMELIN, 1791, used the designation *Arabica westralis* for his species, apparently in error. SCHILDER & SCHILDER (1938 - 39) appear to have misunderstood IREDALE'S intention, thinking he was referring to the true *A. arabica,* and subsequently used *A. westralis* incorrectly for these northwest Australian shells. IREDALE (1939) clarified his use of the name *A. westralis,* which in turn permitted SCHILDER (1941; July 1961) to disregard the unavailable *A. arabica westralis.* It is my considered opinion, however, that geographic isolation, color, and morphological changes in these shells provide valid reasons for further taxonomic consideration. Among other noticeable racial characters, the shells are uniformly larger and heavier, and in this respect seem more closely to approach the east African *M. arabica immanis* SCHILDER & SCHILDER, 1939. The distinctly brown dorsum is typical, and the base and sides of these Dampierian shells are almost white when compared with the orange to orange-brown seen in the other races.

Description:

Shells uniform in appearance, large, solid, cylindrically humped, sloping to the front, blunt to the rear, somewhat bulbously inflated, with the terminals only slightly attenuate, most so in front; margins thickened, excurvate; flattened, flanged abapically; sides steep, concave; base and lip surface narrow, flattened; aperture straight, narrow, widening and constricted in front, curving gradually left at rear; labial and columellar teeth short, strong, well defined, and barely reaching the base from within; interstices deep; fossula large, long, deeply grooved, ribbed with the extended inner lip teeth; terminal ridge straight, defined on either side of the front aperture with parallel brown ridges; color of shell and margins primarily white to light rose-beige, margins irregularly patterned with large, diffuse black spots; terminal collars smudged with grey-black, dorsum covered with chestnut brown ornamentation consisting of broken parallel lateral lines, some interrupted with lacunae of basic shell color; fossula white; columella white with darker shell color visible through the translucent surface; base and interstices off-white to pinkish-beige; teeth brown. A broad mantle line traverses the length of the upper right dorsum.

Type Locality:

The type locality is Broome, Roebuck Bay. The holotype will be deposited in the Western Australian Museum, Perth. Its catalog number will be W. A. M. 32-64.

55. *Mauritia (A.) histrio westralis* (IREDALE, 1935)

Austral. Zool., **8** (2): 108

syn.: *Arabica westralis* IREDALE. Austral. Zool., vol. 8, pt. 2, p. 108

Localities **7, 77, 66, 40, 5, 68**

HEDLEY (1915): **79** (*ex* BRAZIER, 1882) as *reticulata* MARTYN, 1782

IREDALE (1935), STEADMAN & COTTON (1946), ALLAN (1956): "Western Australia"

SCHILDER (1941): **7, 12, 79**

WEAVER (1960): **53**

Dimensions of Northwest Australian shells

	L	W	H	lip	col
Largest shell:	71.6	47.6	35.7	30	26
Smallest shell:	64.4	43.8	35.0	33	25
Average (10 shells):	70.2	45.9	35.2	30	24

Lemurian shells (SCHILDER Prodrome measurements):

	L	W	H	lip	col
	57.0	33.8		25	20

Lemurian shells (Cate Coll. Nos. 1660, 2151)

	L	W	H	lip	col
Largest shell:	60.9	39.3	33.0	34	23
Smallest shell:	45.1	26.0	21.2	30	23
Average (4 shells):	53.2	32.7	27.0	32	25

Cerf Island, Seychelle Islands (Cate Coll. No. 1806)

	L	W	H	lip	col
Largest shell:	44.0	24.0	19.9	32	26
Smallest shell:	40.7	22.8	18.6	32	24
Average (4 shells):	42.1	26.7	18.9	31	25

Ten shells were examined. The species is common in Roebuck Bay. Although *Arabica histrio* is clearly distinct, one is impressed by the resemblance of this species to certain others as to morphology, color, and ornamentation, so much so that one wonders if they are not all allopatric races of a common stock. *Arabica histrio, A. depressa* GRAY, 1824, *A. grayana* SCHILDER, 1930, and *A. maculifera* SCHILDER, 1932 adapt themelves well to a concept of racial division of a species. One significant trait is the presence of a broad, brown color banding, noticeable in the above species as a constant background to the surface markings that, among other things, seems to link the

species together. It is not clear why Iredale (1935) disregarded and failed to recognize *A. histrio* in describing his *A. westralis.* The omission becomes more conspicuous with his use of *A. arabica* (Linnaeus, 1758) and *A. eglantina* (Duclos, 1833) for comparison with his new taxon.

The *Cypraea histrio* of Gmelin ranges in a northern arc from East Africa to India, Andaman Islands, Cocos Keeling Island, Southwest Java, and southward into Northwestern Australia. Authors have suggested that there is no difference between the Lemurian *Arabica histrio* and comparable shells from Malaya. This could be so, but in the Seychelle Islands, and in the Dampierian region, there exists a significant difference in the species. The Cerf Island specimens -- a series of four with all the identifying characters of *A. histrio* -- reveal an interesting story in shell statistics. They are surprisingly small, short, narrow, and the teeth are correspondingly finer. All of the shells are fully adult and well developed. In the East African *A. histrio, s. s.,* there is an equal degree of variation in size, shell shape, and color. One can even detect a color, marking, and morphological gradation into the species *A. grayana* Schilder, 1930.

The southeastern end of the cline seems to be reached in the West Australian region. However, of all the specimens I have had for comparison the smallest is larger than those from anywhere else. A bulla specimen measures 66 millimeters. Although the ornamental markings on the shell are much the same, the overall change in the species is reminiscent of the change found in *Cypraea tigris schilderiana* Cate, 1961. The shells are much heavier in structure, the marginal callus is rounded, more ponderous, thicker, more heavily flanged, and -- possibly inconsequentially -- the characteristic spire blotch appears larger, normally six millimeters in diameter.

It therefore would seem these Northwest Australian shells deserve the recognition Iredale had in mind for them (see Iredale, 1939, pl. 28, figs. 3 and 4).

Cypraea Linnaeus, 1758
(*Cypraea* Linnaeus, 1758)
56. *Cypraea* (*C.*) *tigris pardalis* Shaw, 1785
Vivar. natur. Misc., **6**, plt. 193
Localities **7, 77, 73, 90, 40, 17**
Hedley (1915) (*ex* Menke, 1843), Iredale (1935): West Australia
Schilder (1941): **7, 12, 79**
Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	93.5	60.9	47.4	30	21
Smallest shell:	84.7	60.0	46.6	25	24

Four shells were examined. The species is relatively uncommon. More *Cypraea tigris pardalis* are evidently found during July and August than at any other time of the year; this seems to hold true at Exmouth Gulf and at North West Cape. Representative specimens from Quobba Point and Cape Leveque are in the Whitworth Collection, Geraldton. An interesting note is that *C. tigris pardalis* and *Arabica histrio* (Gmelin, 1791) are often found together.

(*Lyncina* Troschel, 1863)
57. *Cypraea* (*L.*) *lynx vanelli* Linnaeus, 1758
Syst. Nat., Ed. 10, p. 720
Localities **40, 7, 77, 11, 73, 17**
Hedley (1915) (*ex* Menke, 1843): Western Australia
Iredale (1935): West Australia
Schilder (1941): **7, 12, 79**
Allan (1956): North-West Australia
Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	52.3	30.6	26.3	29	20
Smallest shell:	29.2	17.7	15.0	24	18

Nine shells were examined. The species is common, with the center of distribution apparently at Roebuck Bay. The largest specimens are from Broome, and the smaller shells come from Exmouth Gulf.

58. *Cypraea* (*L.*) *vitellus vitellus* Linnaeus, 1758
Syst. Nat., Ed. 10, p. 721
Localities **81, 17, 40, 7, 77, 11**
Hedley (1915) (*ex* Menke, 1843), Iredale (1935): West Australia
Schilder (1941): **7, 12, 79**
Cotton (1950): **52** (56.0 mm)
Allan (1956): Dampierian Region
Weaver (1960): **53**

	L	W	H	lip	col
Largest shell:	71.0	43.9	37.7	31	27
Smallest shell:	28.5	20.2	16.8	22	18

Four specimens from Cable Beach, three from Exmouth Gulf and four from Broome were examined. These shells are not plentiful at Broome, but a few are found from time to time, as is the case also at Cable Beach. From the number of dead shells washed in to the beaches, the species seems to be more plentiful in the North West Cape -- Exmouth Gulf area.

59. *Cypraea* (*L.*) *reevei* Sowerby, 1832
Conch. Illust., fig. 52 (London)
Localities **78, 10, 87, 83, 89a**
Hedley (1915): **44** (*ex* Reeve, 1845)
Iredale (1935): West Australia
Steadman & Cotton (1946): Western Australia
Schilder (1941): **45, 42, 87, 72**
Allan (1956): Southwestern Australia

	L	W	H	lip	col
Largest shell:	42.0	27.6	24.2	31	23
Smallest shell:	26.4	15.5	13.3	28	21

Eleven shells were examined. This uncommon species lives well beyond the low tide mark in deep water and seems nearly always to exhibit varying degrees of damage and wear. The anterior terminal edges are often broken, the dorsum is seldom found without the effects of wave and sand action, because the shells are usually picked up on the beach after storms. A live collected shell is a rarity. Though predominantly a southern species, it does range into Western Australia. Three live specimens were collected in craypots from 15 fathoms off Turtle Dove Shoal, 37 miles west south west of Dongara. Dead shells have been picked up at Geraldton and adjacent beaches. These northern shells seem to be smaller and more globular than those from Swan River and southward.

60. *Cypraea* (*L.*) *carneola carneola* LINNAEUS, 1758

Syst. Nat., Ed. 10, p. 719

Localities **66, 40, 7, 77, 89a**

HEDLEY (1915): **46** (*ex* VERCO, 1912)

SCHILDER (1941): **7, 12, 79, 68, 69, 22**

WEAVER (1960): **53**

	L	W	H	lip	col
Largest shell:	37.2	22.4	19.2	29	23
Smallest shell:	22.1	14.0	11.7	22	21

Thirteen shells were examined. Despite the relatively large number of specimens collected for this study, the species is fairly uncommon in the Exmouth Gulf area, and even more scarce in Roebuck Bay. Cumulatively, the shells average comparatively smaller than those collected on the eastern Australian coast. This species seems to be more abundant at certain seasons than at others.

Explanation of Table 1

The occurrence of the cypraeid species in Western Australia as reported by various authors is listed in Table 1. The columns, arranged arbitrarily, are designated as follows:

Column 1 (C) CATE, 1964 (this report)
Column 2 (S) SCHILDER, 1963 (personal communication)
Column 3 (I) IREDALE, 1935, 1939
Column 4 (W) WEAVER, 1960
Column 5 (A) ALLAN, 1956
Column 6 (Co) COTTON *et al.*, 1946, 1950

The systematic arrangement used in Table 1 and in the text follows that of SCHILDER & SCHILDER, 1939.

	C	S	I	W	A	Co
Pustularia SWAINSON						
bistrinotata bistrinotata				+		
cicercula cicercula	+	+		+		
globulus globulus	+		+			
Staphylaea JOUSSEAUME						
limacina facifer	+	+				
nucleus nucleus	+			+		
staphylaea staphylaea	+			+	+	+
Erosaria TROSCHEL						
caputserpentis kenyonae	+	+		+		+
caputserpentis reticulum	+	+				
cernica viridicolor	+	+	+			
erosa purissima	+	+	+	+		
helvola citrinicolor	+	+	+	+	+	+
labrolineata labrolineata	+	+				
poraria poraria	+	+			+	
miliaris diversa	+	+	+		+	+
wilhelmina			+			+
Monetaria TROSCHEL						
annulus annulus	+	+				
moneta rhomboides	+	+	+	+	+	
Erronea TROSCHEL						
caurica blaesa	+	+	+		+	+
cylindrica sowerbyana	+	+	+	+	+	+
errones proba	+	+	+	+	+	
ovum ovum	+	+				
pyriformis smithi	+	+			+	+
subviridis dorsalis	+	+	+			
walkeri continens			+			
angustata						+
Notocypraea SCHILDER						
declivis		+	+		+	+
pulicaria	+	+			+	
Palmadusta IREDALE						
asellus asellus	+	+	+		+	+
clandestina clandestina	+	+	+	+	+	
fimbriata fimbriata	+	+		+		
gracilis hilda	+	+	+		+	+
hammondae	+	+	+			
lutea bizonata	+	+	+		+	+
punctata punctata		+	+	+		
saulae saulae	+					
ziczac ziczac	+	+		+		
Blasicrura IREDALE						
hirundo cameroni	+	+	+	+	+	
pallidula simulans	+	+	+		+	
quadrimaculata thielei	+	+	+		+	+
stolida stolida	+	+				
stolida brevidentata	+	+		+		

	C	S	I	W	A	Co
Cribraria JOUSSEAUME						
chinensis chinensis		+				+
chinensis whitworthi	+					
cribraria fallax	+	+		+	+	+
teres teres	+	+		+		
Bernaya JOUSSEAUME						
catei	+	+				
Zoila JOUSSEAUME						
decipiens	+	+			+	
friendii friendii	+	+			+	+
friendii vercoi	+				+	+
marginata	+	+				
thersites thersites			+			
venusta venusta	+	+	+		+	+
venusta sorrentensis	+	+				
rosselli	+				+	+
episema	+	+	+		+	+
Luria JOUSSEAUME						
isabella rumphii	+	+	+	+	+	
Talparia TROSCHEL						
argus argus	+	+	+			
talpa talpa	+	+		+		+
Mauritia TROSCHEL						
arabica arabica		+	+	+	+	
arabica brunnescens	+					
eglantina couturieri	+	+		+	+	+
histrio	+	+	+	+	+	+
mauritiana regina		+				+
Cypraea LINNAEUS						
carneola carneola	+	+	+	+	+	
lynx vanelli	+	+	+	+	+	
reevei	+				+	+
tigris pardalis	+	+		+		
vitellus vitellus	+	+	+	+		+

LITERATURE CITED

ALLAN, JOYCE

1956. Cowry shells of world seas. Georgian House, Melbourne. i - x; pp. 1 - 170: plts. 1 - 15.

BRAZIER, JOHN

1882. Distribution and geographic range of cowries in Australasia. (an unpublished reprint from the Sydney Mail, Dec. 2, 1871.)

1883. The habitat of *Cypraea citrina.* Proc. Linn. Soc. N. S. Wales, 7: 322 - 323.

CATE, CRAWFORD NEILL

1960. A new subspecies of *Cypraea saulae* GASKOIN, 1843. The Veliger 3 (2) : 34 - 37; plt. 5; 1 map; 1 table. (1 Oct. 1960)

CATE, CRAWFORD NEILL

1961 a. Rediscovery of *Cypraea marginata* GASKOIN, 1848. The Veliger, 3 (3) : 76 - 78; plt. 14; figs. 1 - 4. (1 Jan. 1961)

1961 b. Description of a new Hawaiian subspecies of *Cypraea tigris* (LINNAEUS, 1758). The Veliger, 3 (4) : 107 - 109; plt. 19; figs. 1 - 4. (1 April 1961)

1962. Comparison of two rare cowrie species (Gastropoda) The Veliger 5 (1) : 6 - 14; plts. 1 - 4; 2 text figs. (1 July 1962)

COTTON, BERNARD CHARLES

1950. Mollusca from Western Australia. Rec. So. Austral. Mus., 9 (3) : 333 - 338.

GATLIFF, JOHN HENRY

1916. Description of two Australian cowries. Victorian Nat. 32: 147.

HEDLEY, CHARLES

1915. Preliminary Index of the Mollusca of Western Australia. Journ. Roy. Soc. Western Austral. Mus., 9 (3) : 333 - 338.

IREDALE, TOM

1914. Report on Mollusca collected at the Monte Bello Islands. Proc. Zool. Soc. London, 1914: 665 - 675.

1935. Australian cowries, part 1. Autral. Zool. 8 (2) : 96 to 135; plts. 8 - 9.

1939. Australian cowries, part 2. Austral. Zool., 9 (3) : 297 - 323; plts. 27 - 29.

KENYON, AGNES F.

1897. Description of two new *Cypraea.* Proc. Linn. Soc. N. S. Wales, 22: 145.

1902. Undescribed variety of *Cypraea.* Journ. Conch., 10: 183 - 184.

MENKE, KARL THEODOR

1843. Molluscorum Novae Hollandiae specimen. Hannover, 46 pp.

REEVE, LOVELL AUGUSTUS

1835. "Mr. Reeve exhibited . . . . previously undescribed . . ." Minutes of meeting of May 28, 1835. Proc. Zool. Soc. London, 1835: 68. (2 Sept. 1835)

SCHILDER, FRANZ ALFRED

1941. Verwandtschaft und Verbreitung der Cypraeacea. Arch. Molluskenk. 73 (2 - 3) : 57 - 120; 2 plts.

1961. The size of *Mauritia arabica.* The Veliger 4 (1) : 15-17. (1 July 1961)

1963. Further remarks on two rare cowrie species. The Veliger, 5(4) : 125 - 128; 3 tables.

SCHILDER, FRANZ ALFRED, & MARIA SCHILDER

1938 - 1939. Prodrome of a monograph on living Cypraeidae. Proc. Malacol. Soc. London, 23(3 - 4) : 119 - 231.

1952. Ph. Dautzenberg's collection of Cypraeidae. Mém. Inst. Roy. Sci. Nat. Belgique (2) 45: 1 - 243; 4 plts.

SOWERBY, GEORGE BRETTINGHAM (2nd of name)

1870. Thesaurus conchyliorum; 26 - 28: *Cypraea.* (London) 58 pp.; 37 plts.

STEADMAN, W. R., & BERNARD C. COTTON

1946. A key to the classification of the cowries (Cypraeidae). Records South Austr. Mus. 8: 503 - 530; 6 plts.

VERCO, J. C.
1912. Shells of the Great Australian Bight. Trans. Roy. Soc. South Austral., 36: 206 - 232; plts. 10 - 14, 16.

WEAVER, CLIFTON S.
1960. Hawaiian scientific expedition finds rare western Australian volutes. Hawaiian Shell News 8 (12): 1 and 3. [new series 10] October 1960.

The Mollusca of the Santa Barbara County Area

Part I - Pelecypoda and Scaphopoda

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DALL (1921) LISTED RANGES of many species of mollusks as terminating, either in their northern or southern extremes, in Santa Barbara County, California. Many of these records were based on the work of Lorenzo G. Yates, whose faunal list of the county (1890 b) and other papers (1877 and 1890 a) included many original collecting data. Since the time of YATES and DALL there has not been a comprehensive list of the species in this area, although BERRY (1956), HEWATT (1946), BARNARD & HARTMAN (1959), and GRAU (1959) have published a few records. There is need of a list of species currently collected from this region in order to substantiate the previously published records.

During the past two years, in connection with a course at the University of California at Santa Barbara, I have attempted to make as complete a survey of the mollusks of the Santa Barbara County area as I could, revising the existing collection of the University in the process, and adding such material to that collection as might prove useful. The following list is the result of that work. Because of the time involved in the preparation of this table and the difficulty of identifying the Gastropoda, Amphineura, and Cephalopoda at this time, it was decided to restrict this paper to the Pelecypoda and Scaphopoda and to complete the work on the other three groups at a later date.

Santa Barbara County is a rectangle of land with a coast line of about 100 miles, not including its three channel islands, San Miguel, Santa Rosa, and Santa Cruz. Anacapa, the southern member of this chain of islands, is in Ventura County. Most authors agree that, with regard to shore and shallow water fauna, Point Conception, in Santa Barbara County, is a significant dividing point between the faunas of Northern California, Oregon, and Washington, and that of Southern California. For additional information and discussion of this transition two types of account may be found in SCHENCK & KEEN (1936) and NEWELL (1948). The transition is not abrupt at any one point, but the bulk of the change takes place between Point Arguello and Point Conception. This transition is ascribed to currents and a temperature gradient. About half of the 100-mile coast line lies north of Point Conception. I collected beach specimens on the north side of Point Conception, finding on one trip over 75 species of mollusks. Many of these specimens confirmed what had been questionable northern or southern range limits.

Most of the Santa Barbara coastline is sand beach, with one headland after another jutting into the long expanse of sand. There is one feature of special interest with regard to the sand itself -- the fact that it undergoes a yearly cycle of movement along the coast. About half of the year most of the rocks on the University Campus beach, for instance, are covered by sand. As a result, there is never much life on these rocks. They are too often covered and abraded by the sand to bear even the limpets and chitons typical of somewhat less sandy rocks. When they do become uncovered, green algae are about all that gets a foothold before the rocks are once more buried, though, no doubt, the juvenile stages of other plants and of animals begin to settle during the uncovered period. The extent to which the sand moves varies along the southern Santa Barbara coastline.

Another aspect of Santa Barbara beaches is of interest: tar. There are several tar seeps along the coast, the presence of tar and oil being further testified to by the many offshore oil rigs. The tar seeps are especially productive in the U. C. S. B. -- Coal Oil Point area, the latter being so named for obvious reasons. The tar continually

oozes out of the offshore cracks and rises to the surface in masses. It floats around, and much of it comes to shore where it is deposited along the high tide line. Many of the intertidal rocks in certain areas, such as at Goleta Point, are almost covered with a layer of sticky tar. However, it is surprising, that, even in the most heavily tarred areas, there are always a few hardy mollusks that do not seem to be affected by the tar and the odor of kerosene -- a few limpets, chitons and mussels.

Some time ago I held the probably common belief that picking up beach specimens was a "wrong" way to collect mollusks. I have since modified this position, for I have added many species to the Santa Barbara list from materials washed up on the Campus beach, species which may live well off-shore. In this connection, there is one problem in collecting beached material in Santa Barbara County, one true of many southern California areas -- that of the mixing of freshly-dead and fossil material on the beaches. For instance, material from the Late Pliocene or Early Pleistocene Santa Barbara formation occasionally washes out to the beaches, and there are even places where this formation extends almost to the water line. There is, in addition, a Recent marine terrace, along the cliffs in the immediate U. C. S. B. area. It contains a fauna much like that of Puget Sound. If I had not finally made a representative collection of the formation, I might still be puzzling over some beach specimen of *Thais lamellosa, Acmaea instabilis,* or *Calyptraea fastigiata.* The material is in a remarkable state of preservation, periostracum and bits of ligament remaining on many of the clams.

To complicate the situation further, there is Goleta Slough, the remains of what once was a large lagoon. The existence of this lagoon in fairly recent times is evidenced by sub-fossil mollusks along its banks and in Indian kitchen middens in the surrounding area. Dall (1921) and other authors of his period and before, list the Goleta area as the northernmost outpost of many of the southern California lagoon species. Species typical of these two deposits include *Aequipecten,* two species of *Chione,* one of *Tagelus,* and one of *Sanguinolaria.* None of these forms have been recently found living in the slough, which, as far as I can see, contains only *Cerithidea, Assiminea,* and *Melampus.* Material from these two sub-fossil beds, natural and Indian created, may be found washed up on the nearby beaches.

There seem to be two types of headlands jutting out into the sand beaches: rubble points like Rincon Point, and large rock points, like Goleta Point (some points are combinations of these two types). The rubble points have their own typical fauna. Special demands are placed on the inhabitants by the abrading sand. Such an area typically has *Acmaea fenestrata, Mopalia porifera, M. acuta* and *M. muscosa.* The large rock points support a fauna similar to that in like areas throughout the coast -- *Mytilus* spp., *Septifer, Thais, Lasaea, Nuttallina,* and the several species of *Acmaea.*

As well as these two headland types, there are a few rock reefs (such as Carpenteria reef) that are intertidal. There are numerous offshore reefs, some exposed above the bottom sediments as far down as forty feet. These reefs are composed of the same rocks that compose both the cliffs along the coast and the large rock points, the Miocene Monterey shale.

By far the commonest species washed up on Santa Barbara beaches is the boring myad, *Platyodon cancellatus.* The intertidal and subtidal reefs are ideal for its existence, and the enormous number of valves washed up all along the coast testifies to its presence by the millions. Also, the reefs, including the famous one at Carpenteria, abound in rock borers and the associated nestlers. I have found all the common pholads at Carpenteria, as well as washed up on the Campus beach, including *Chaceia, Parapholas,* the three species of *Penitella, Netastoma,* and *Zirfaea.* The nestlers *Thracia curta, Diplodonta orbella, Petricola carditoides, P. californiensis, Cumingia,* and *Hiatella* are found in old pholad holes.

In general, diving is not as successful as it is in other places in California, mainly because fine offshore sediments and temporary plankton blooms make for poor visibility. The subtidal reefs are scattered and are often sand-covered. The immediate area of the kelp beds is best; most fruitful is a trip to the channel islands, where rocks are exposed as deep as SCUBA equipment allows most divers to go, i. e., 150 feet.

Forms typical of the kelp holdfast area of the rock-sand bottom include *Jaton, Maxwellia gemma, Mitra idae* and *Astraea undosa. Zonaria, Megathura,* and *Haliotis* spp. are to be found on the nearby underwater reefs.

On the sand bottom near the holdfasts may be found *Kelletia,* two species of *Nassarius,* two species of *Olivella,* and one of *Acteon.* Many unusual forms turn up in beached kelp holdfasts or in siftings from 30 to 40 feet, such as *Lamellaria orbiculata, Volvulella cylindrica, Acmaea rosacea* and *Calliostoma splendens.*

Most of the elements of the typical southern California fauna reach the southern Santa Barbara County area, many of them being scarce, however. In general, Santa Barbara intertidal populations are small, but the variety is surprising. The same seems to be true of the shallow water fauna. I would guess that if one were to collect both in the northern and in the southern portions of this county, carefully and consistently, as well as on the three channel islands, Santa Barbara would prove to have the largest fauna of any of the California counties.

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EXPLANATION OF THE TABLE

The species are listed in taxonomic order, following Keen (1963). The following abbreviations are used for localities in the Santa Barbara County area (see map):

1 - Point Conception, including about five miles north (Jalama) and south
2 - Gaviota south to Tajiguas
3 - Coal Oil Point
4 - University of California, Santa Barbara, and Goleta area
5 - Hope Ranch
6 - Santa Barbara City and Harbor
7 - Carpenteria
8 - Rincon Point (partly in Ventura County)
9 - San Miguel Island
10 - Santa Rosa Island
11 - Santa Cruz Island
12 - Anacapa Passage, including area just off the west end of Anacapa Island
13 - Anacapa Island (Ventura County)

The following abbreviations are used for the names of persons reporting species in published lists or in substantial lists provided to me for this table.

BH - Barnard & Hartman (1959)
B - Berry (1956)
EC - Eugene Coan
FH - Faye Howard
G - Grau (1959)
H - Hewatt (1946)
M - James McLean

PELECYPODA

Nuculidae

Acila castrensis (Hinds, 1843) - 11, 12 (B)
Nucula cf. *N. cardara* Dall, 1916 - several stations (BH)
Nucula tenuis (Montagu, 1808) - 11 (B)

Nuculanidae

Nuculana acuta (Conrad, 1832) - 11 (H) [reported in quotation marks]
Nuculana hamata (Carpenter, 1864) - 12 (B)
Nuculana taphria (Dall, 1896) - 4, 6 (EC); 5 (FH); 11 (B)
Yoldia cooperi Gabb, 1865 - 4 (EC)

Glycymerididae

Glycymeris subobsoleta (Carpenter, 1864) - 9 (EC); 10 (B) [as *G. corteziana*]

Philobryidae

Philobrya setosa (Carpenter, 1864) - 11 (H)

Pinnidae

Atrina oldroydii Dall, 1901 - "off Santa Barbara" (EC)

Mytilidae

Adula californiensis (Philippi, 1847) - 1,3,4 (EC); 7 (FH)
Adula falcata (Gould, 1851) - 1, 3, 4 (EC); 5 (FH)
Amygdalum pallidulum (Dall, 1916) - 12 (B)
Hormomya adamsiana (Dunker, 1857) - 11 (H); 13 (EC)
Lithophaga plumula (Hanley, 1844) - 3, 4, 7, 13 (EC); 1 (M); 11 (H)
Modiolus capax Conrad, 1837 - 1, 4, 7, 13 (EC)
M. modiolus (Linnaeus, 1758) - 11 (H)
M. rectus Conrad, 1837 - 4, 6 (EC)
Mytilus californianus Conrad, 1837 - 1, 2, 3, 4, 6, 8 (EC); 5 (FH); 11 (H)
M. edulis Linnaeus, 1758 - 1, 3, 4, 6, 7 (EC); 5 (FH)
Septifer bifurcatus (Conrad, 1837) - 1, 2, 3, 4, 6, 7 (EC); 5, 10 (FH); 11 (H)

Ostreidae

Ostrea lurida Carpenter, 1864 - 4, 6 (EC); 5 (FH)

Pectinidae

Aequipecten circularis aequisulcatus (Carpenter, 1864) - 4 (EC); "S. B. Ids." (G)
Chlamys hastata (Sowerby, 1842) - "S. B. Ids." (G); 11 (H); 12 (B)
C. pugetensis (Oldroyd, 1920) - "S. B. Ids." (G)
Cyclopecten catalinensis (Willett, 1931) - 11 (G)
Delectopecten randolphi tillamookensis (Arnold, 1906) - "S. B. Ids." (G)
D. vancouverensis (Whiteaves, 1893) - "S. B. Ids." (G)

Hinnites multirugosus (GALE, 1928)
- 1, 2, 3, 4, 6, 13 (EC); 5, 10 (FH); 11 (H)
Leptopecten latiauratus (CONRAD, 1837) - 10 (FH)
L. monotimeris (CONRAD, 1837)
- 1, 4, 6 (EC); 5 (FH); 11 (H)
Pecten diegensis DALL, 1898
- 1, 4 (EC); "S. B. Ids." (G); 12 (B)

LIMIDAE

Lima hemphilli HERTLEIN & STRONG, 1946
- 4, 6, 7 (EC); 5 (FH); 11 (H)(B)

ANOMIIDAE

Anomia peruviana D'ORBIGNY, 1846
- 4 (EC); 5 (FH); 11 (H)
Pododesmus cepio (GRAY, 1849)
- 1, 2, 3, 4 (EC); 5, 10 (FH)

CHAMIDAE

Chama pellucida BRODERIP, 1835
- 4, 6, 7, 8, 13 (EC); 5, 10 (FH); 10 (B); 11 (H)
Pseudochama exogyra (CONRAD, 1837)
- 3, 4, 6, 7, 13 (EC); 5 (FH)
P. granti STRONG, 1934 - 12 (B)

CARDITIDAE

Cardita longini BAILY, 1945 - 10, 12 (B)
C. ventricosa GOULD, 1850
- several stations (BH); 11 (H)
Glans carpenteri (LAMY, 1922)
- 4, 6, 7, 13 (EC); 5 (FH); 11 (H)
Milneria kelseyi DALL, 1916 - 11 (H)

ERYCINIDAE

Lasaea cistula KEEN, 1938 - 4, 13 (EC)

KELLIIDAE

Kellia laperousii (DESHAYES, 1839)
- 1, 4, 6, 7, 13 (EC); 5 (FH); 11 (H)

MONTACUTIDAE

Mysella sp. - 4 (EC)

LUCINIDAE

Epilucina californica (CONRAD, 1837) - 3, 4, 5, 7 (EC)
Here excavata (CARPENTER, 1857) - 4 (EC)
Lucinisca nuttalli (CONRAD, 1837) - 4 (EC)
Lucinoma cf. *L. aequizonata* (STEARNS, 1890)
- 4 (EC) "beach"

UNGULINIDAE

Diplodonta orbella (GOULD, 1852)
- 3, 4, 6, 7, 13 (EC); 1, 5, 10 (FH)
D. sericata (REEVE, 1850) - 11 (H)
[juv. *D. orbella*? (EC)]
D. cf. *D. subquadrata* (CARPENTER, 1856) - 12 (B)
[juv. *D. orbella*? (EC)]

CARDIIDAE

Clinocardium nuttalli (CONRAD, 1837)
- 4, 6 (EC); 5 (H)
Laevicardium substriatum (CONRAD, 1837) - 7 (EC)
Nemocardium centifilosum (CARPENTER, 1864)
- 10 (EC); 11 (B)(H); 12 (B)
Trachycardium quadragenarium (CONRAD, 1837)
- 4, 5, 6 (EC); 10 (FH); 11 (B)(H)

VENERIDAE

Amiantis callosa (CONRAD, 1837) - 5 (FH)
Chione californiensis (BRODERIP, 1835) - 6 (EC)
C. undatella (SOWERBY, 1835) - 4, 6 (EC)
Compsomyax subdiaphana (CARPENTER, 1864)
- 4 (EC); several stations (BH); 11 (B)(H)
Notirus lamellifer (CONRAD, 1837)
- 1, 3, 4 (EC); 11 (H); 10 (FH)
Protothaca laciniata (CARPENTER, 1864)
-4, 6 (EC); 5 (FH)
P. staminea (CONRAD, 1837)
- 1, 3, 4, 6, 7, 8 (EC); 5 (FH)
P. tenerrima (CARPENTER, 1856) - 4(EC)
Saxidomus nuttalli CONRAD, 1837
- 1, 4, 6 (EC); 5, 10 (FH)
Tapes semidecussata REEVE, 1864 - 1, 7? (FH)
Tivela stultorum (MAWE, 1823)
- 3, 4, (EC); 5 (FH); 11 (H)
Transennella tantilla (GOULD, 1853)
- 1, 3, 4, 6 (EC); 5, 10 (FH); 11 (H)
Ventricolaria fordii (YATES, 1890) - 1, 3, 4(EC)

PETRICOLIDAE

Petricola californiensis PILSBRY & LOWE, 1932
- 3, 4, 7 (EC)
P. carditoides (CONRAD, 1837)
- 1, 3, 4, 6 (EC); 5, 7, 8 (FH); 11 (H)

COOPERELLIDAE

Cooperella subdiaphana (CARPENTER, 1864) - 11 (H)

MACTRIDAE

Spisula cf. *S. planulata* (CONRAD, 1837) - 12 (B)
Tresus nuttallii (CONRAD, 1837) - 1, 4, 6 (EC); 10 (FH)

TELLINIDAE

Macoma indentata CARPENTER, 1864 - 4 (EC)
M. inquinata (DESHAYES, 1854) - 1, 4 (EC); 5 (FH)
M. nasuta (CONRAD, 1837) - 4, 6 (EC); 10 (FH)
M. secta (CONRAD, 1837) - 4, 6 (EC)
M. yoldiformis CARPENTER, 1864
- 4 (EC); several stations (BH); 11 (H)
Florimetis biangulata (CARPENTER, 1855)
- 4 (EC); 5 (FH)
Tellina bodegensis HINDS, 1844 - 1, 4, 10 (EC)

T. cf. *T. buttoni* DALL, 1900 - 4 (EC); 5 (FH)
T. carpenteri DALL, 1900 - 11, 12 (B)

DONACIDAE

Donax gouldii DALL, 1921 - 4 (EC)

GARIDAE

Gari californica (CONRAD, 1849) - 3, 4, 6 (EC); 11 (H)
Sanguinolaria nuttallii CONRAD, 1837 - 4 (EC)

SEMELIDAE

Cumingia californica CONRAD, 1837
- 3, 4, 6, 7, 13 (EC); 5, 10 (FH)
Semele decisa (CONRAD, 1837) - 3, 4 (EC)
S. incongrua CARPENTER, 1864 - 11 (H); 12 (B)
S. rubropicta DALL, 1871 - 3, 4 (EC); 5 (FH)
S. rupicola DALL, 1915 - 1, 3, 4, 13 (EC); 11 (H)

SOLECURTIDAE

Tagelus californicus (CONRAD, 1837) - 4, 6 (EC)

SOLENIDAE

Siliqua patula (DIXON, 1789) - 4, 6 (EC)
Solen rosaceus CARPENTER, 1864 - 4 (EC)
S. sicarius GOULD, 1850 - several stations (BH); 11 (H)

MYIDAE

Cryptomya californica (CONRAD, 1837)
- 4, 6 (EC); 5 (FH)
Platyodon cancellatus (CONRAD, 1837)
- 1, 3, 4, 7 (EC); 5, 10 (FH)
Sphenia sp. - 4 (EC)

HIATELLIDAE

Hiatella arctica (LINNAEUS, 1767)
1, 3, 4, 6, 7, 13 (EC); 5 (FH); 11 (H); 12 (B)
Panopea generosa GOULD, 1850 - 4 (EC)
Saxicavella pacifica DALL, 1916 - several stations (BH)

PHOLADIDAE

Barnea subtruncata (SOWERBY, 1834) - ?4 (EC)
Chaceia ovoidea (GOULD, 1851) - 4, 7 (EC); 1 (FH)
Netastoma rostrata (VALENCIENNES, 1846)
- 1, 4, 7 (EC)
Parapholas californica (CONRAD, 1837)
- 1, 3, 4, 7 (EC)
Penitella conradi VALENCIENNES, 1846 - 4, 13 (EC)
P. gabbi (TRYON, 1863) - 4, 7 (EC)
P. penita (CONRAD, 1837) - 1, 3, 4, 6, 7 (EC); 5 (FH)
Zirfaea pilsbryi LOWE, 1931 - 4 (EC); 10 (FH)

TEREDINIDAE

Teredo cf. *T. diegensis* BARTSCH, 1916 - 3 (EC)

PANDORIDAE

Pandora punctata CONRAD, 1837 - 4 (EC)

LYONSIIDAE

Entodesma inflata (CONRAD, 1837) - 10 (EC); 11 (H)
E. saxicola (BAIRD, 1863) - 1, 4, 6, 13 (EC); 7, 10 (FH)
Lyonsia californica CONRAD, 1837 - 6 (EC); 11 (H)
Mytilimeria nuttallii CONRAD, 1837
- 1, 4, 6, 7, 8 (EC); 5, 10 (FH); 11 (H)

THRACIIDAE

Thracia curta CONRAD, 1837 - 3, 4, 7 (EC)

CUSPIDARIIDAE

Cardiomya californica (DALL, 1886) - 12 (B)

SCAPHOPODA

DENTALIIDAE

Dentalium neohexagonum SHARP & PILSBRY, 1897
- 4 (EC); 5 (FH)

LITERATURE CITED

BERRY, SAMUEL STILLMAN

1956. Mollusca dredged by the *Orca* off the Santa Barbara Islands, California, in 1951. Journ. Washington Acad. Sci., 46 (5): 150 - 157; 9 figs. (May 1956)

BARNARD, J. LAURENS, & OLGA HARTMAN

1959. The sea bottom off Santa Barbara County: biomass and community structure. Pacific Naturalist 6 (6): 1 - 15; 7 figs.; 6 tables. (1 June 1959)

DALL, WILLIAM HEALEY

1921. Summary of the marine shell-bearing mollusks of the north-west coast of America from San Diego, California, to the Polar Sea, mostly contained in the collection of the U. S. National Museum. Smithson. Inst., U. S. Nat. Mus. Bull. 112: pp. 1 - 217; plts. 1 - 22.

GRAU, GILBERT

1959. Pectinidae of the Eastern Pacific. Allan Hancock Pacific Expeditions 23: viii + 308; 57 plts. Univ. South. Calif. Press. (25 September 1959)

HEWATT, WILLIS G.

1946. Marine ecological studies on Santa Cruz Island, California. Ecol. Monographs 16 (3): 185 - 210; 2 figs; 2 tables.

KEEN, A. MYRA

1963. Marine molluscan genera of western North America: an illustrated key. Stanford Univ. Press; 1 - 126; illust.

NEWELL, IRVIN M.

1948. Marine molluscan provinces of western North America: a critique and a new analysis. Proc. Amer. Philos. Soc. 92 (3): 155 - 199; 7 figs.; 2 tables. (July 1948)

SCHENCK, HUBERT G., & A. MYRA KEEN

1936. Marine molluscan provinces of western North America. Proc. Amer. Philos. Soc. 76 (6): 921 - 938; 6 figs.; 1 table.

YATES, LORENZO GORDIN

1877. The mollusca of Santa Rosa Island, California. U. S. Quart. Journ. Conch. (Leads) 1 (10): 182 - 185.

1890 a. The mollusca of the Channel Islands of California. Ninth Ann. Reprt., State Mineralogist for 1889: 175 - 178. State Min. Bureau.

1890 b. The mollusca of Santa Barbara County, California, and new shells from the Santa Barbara Channel. Santa Barbara Soc. Nat. Hist. 2: 36 - 48; 2 plts. (August 1890)

Habitats and Breeding Seasons of the Shelf Limpet *Crepidula norrisiarum* Williamson

BY

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(Plate 6)

During the course of some investigations of marine invertebrates in the vicinity of Corona Del Mar, California, and off Point Mugu, California, as well as the offshore islands, observations were incidentally made on the habitats and breeding seasons of *Crepidula norrisiarum* Williamson, 1905. These observations were made between 1948 and 1963. Some of the information obtained is listed in the table below. The earlier investigations were made from the Kerckhoff Marine Laboratory of the California Institute of Technology, the later from the U. S. Naval Missile Center at Point Mugu, California. In the work at Point Mugu, we are indebted to SCUBA divers Billy Scronce and Martin Conboy (USN), who brought in the specimens from Locations 2 and 3.

The records given in the table below indicate that *Crepidula norrisiarum* breeds throughout the year. Of the individuals examined, none that were 25 mm or less in length were found brooding eggs. Of the thirteen individuals on one *Norrisia,* the males averaged 14.1 mm in length, the females 25.0 mm. Tiny, solitary individuals are often found on the same host with the large ones that are paired. Are these potential males for the females that will develop from the current males?

We believe that several new habitats are given and that ten and thirteen individuals per host are rather unusual. That *Crepidula norrisiarum* was found on *Randallia,* a crab that inhabits smooth, open bottom, shows that the limpet is not necessarily confined to a rocky habitat.

In the preparation of this manuscript, we are indebted to Dr. Myra Keen for a helpful suggestion.

Habitats and Breeding Seasons of *Crepidula norrisiarum* Williamson

Month	No. of Individuals	Size in mm	No. Brooding Individuals	No. Capsules	Eggs or larvae per Capsule (Ave.)	Habitat	Location
Jan.	5		1	20	26 larvae	1 *Norrisia*	1
Feb.	4	1.7 - 2.8	0			3 *Mitrella carinata*	2
	1	3.8	0			1 *Nassarius cooperi*	2
	13	4.1 - 28.3	3	24 - 35	24 - eggs, larvae	1 *Norrisia*	2
	10	4.0 - 34.0	1			1 *Norrisia*	2
April	8		?			3 *Randallia bulligera* (crab)	1
	2		1	(larvae with 1.1 mm shells)		1 *Norrisia*	1
June	2		1	19	15 - 30 larvae[1]	1 *Norrisia*	1
Oct.	2	21, 28	1		eggs	2 *Norrisia*	3

Location 1: Off Corona Del Mar, California, from 20 to 50 feet deep.
Location 2: 3½ mi. south of Mugu Rock, near Point Mugu, California, 30 feet deep.
Location 3: Off Anacapa Island, California, 100 yards out from Cat Rock, 55 to 60 feet deep.

[1] With the exception of a very few in the center of a capsule, all the larvae were oriented so that the foot was placed against the wall of the capsule.

Norrisia norrisi (Sowerby, 1838),
48.2 mm in diameter, 40.5 mm high, with thirteen
Crepidula norrisiarum Williamson, 1905, growing on it.

New Species of Mollusks from the Coast of Brazil

BY

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(5 Text figures)

THIS IS THE FIRST in what is hoped to be a series of papers describing new species of mollusks that are coming to light in recent years, due to good opportunities for collecting.

Cl. PELECYPODA

HETERODONTA

SEMELIDAE

Semele SCHUMACHER, 1817

Semele aurora TURSCH & PIERRET, spec. nov.

(Figures 1, 2 and 3)

Shell white, marked with numerous radial color stripes that are pink to bright orange, the area near the umbones flecked or blotched with red. Texture porcelaneous but somewhat translucent, the external rays showing through to the highly enameled interior surface. Outline subovate, with rounded anterior end, posterior end shorter with a definite flexure. Right valve slightly more convex than

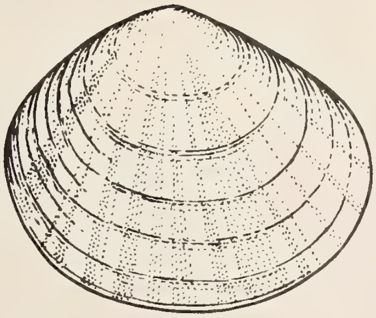

Figure 1: *Semele aurora,* holotype, Stanford Univ. Paleo. Type Coll. no. 9736. Exterior, right valve. × 1. Recent, Rio de Janeiro.

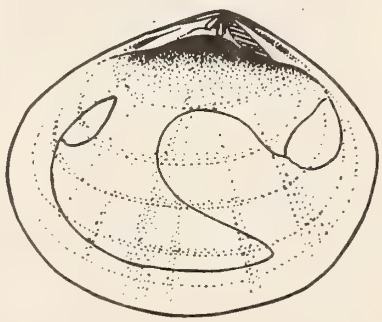

Figure 2: *Semele aurora,* holotype, Stanford Univ. Paleo. Type Coll. no. 9736. Interior, right valve. × 1. Recent, Rio de Janeiro.

left. Sculpture, in addition to growth lines, of coarsely corrugated concentric ribs, finer near beaks, more widely spaced near margins, stronger on the posterior end. Hinge with two cardinal and two lateral teeth in either valve, the anterior cardinals higher, slightly bifid. External ligament supplemented by a resilium in an internal depression or chondrophore behind the two cardinal teeth and nearly parallel to the posterior part of the hinge line. Pallial sinus moderately large.

Dimensions:

(in millimeters)

	Length	Height	Convexity (both valves)
Holotype	48.9	41.8	17.1
Paratype I	38.6	30.6	13.5
Paratype II	38.9	31.4	13.7

Type locality: Off Rio de Janeiro, in 30 fathoms, sand.
Repositories: Holotype, Stanford Univ. Paleo. Type Coll.

no. 9736. Paratype I: Museu Nacional, Rio de Janeiro, no. 3116; Paratype II: American Museum of Natural History, New York.

Discussion: This species seems related to *Semele purpurascens* (GMELIN, 1791) but is readily separated by its coarser concentric ribs and its distinctive color pattern. These differences also apply to *S. proficua* (PULTENEY, 1799). From *S. casali* DOELLO-JURADO, 1949, of the Argentine coast, it is distinguished by its larger size, smaller pallial sinus, and greater proportionate height.

Figure 3: *Semele aurora,* holotype, Stanford Univ. Paleo. Type Coll. no. 9736. Diagram of hinge of right valve. × 1. Recent, Rio de Janeiro.

Cl. GASTROPODA

CTENOBRANCHIATA

PTENOGLOSSA

EPITONIIDAE

Epitonium RÖDING, 1798

Epitonium (Epitonium) arnaldoi TURSCH & PIERRET spec. nov.

(Figure 4)

Shell small, thin, white, rather fragile, imperforate, with numerous costae. Surface between costae shiny, showing no microscopic sculpture. Whorls about 10, convex, attached to one another by the costae. Aperture subcircular, holostomatous. Nuclear whorls $2\frac{1}{2}$, glassy, smooth. Whorls of teleoconch flat-sided, enlarging at an angle of approximately 35°. Costae blade-like, somewhat solid, produced at a sharp angle on the shoulder of the body whorl. Holotype with 10 costae on body whorl. Operculum unknown.

Dimensions:

(in millimeters)

	Length	Width	Number of whorls
Holotype:	11.0	4.5	10.0
Paratype:	5.2	2.9	6+ (probably 2 missing)

Type locality: Trawled off Punta de Juatinga, Lat. 23°22′ S., Long. 48°28′ W., in 50 meters depth.

Repositories: Holotype, Stanford Univ. Paleo. Type Coll. no. 9737; paratype, Museu Nacional, Rio de Janeiro, no. 3118.

Discussion: *Epitonium arnaldoi* seems to be closely related to *E. angulatum* (SAY, 1830). It can be distinguished by the flat-sided whorls of the spire, contrasting to the convexity of *E. angulatum* and also by having more whorls for an equal size; for example, a shell of 16 mm length of *E. angulatum* has 8 whorls, whereas at 11 mm *E. arnaldoi* has 10. From *E. venosum* (SOWERBY, 1844) and *E. foliaceicostum* (D'ORBIGNY, 1842) this new species differs by the number of whorls and the number of costae on the body whorl.

Figure 4: *Epitonium arnaldoi,* holotype, Stanford Univ. Paleo. Type Coll. no. 9737. × 4.4. Recent, Rio de Janeiro.

This species is named after Dr. Arnaldo Campos dos Santos Coelho, Curator of Mollusca at the Museu Nacional of Rio de Janeiro.

Epitonium (Epitonium) mauryi TURSCH & PIERRET spec. nov.

(Figure 5)

Shell moderately large (some adults as large as 25 mm in length), thin, white, imperforate, with numerous costae. Surface between costae shiny, showing no microscopic sculpture. Whorls up to 11 in number, convex, appressed or slightly separated and attached by the costae only. Aperture subcircular, holostomatous. Nuclear whorls very small, smooth. Spire elongated, spire angle approximately 26°. Costae blade-like, rather high, angled at the whorl shoulder, where they reach the maximum height. Body whorl with 13 to 15 costae. Operculum unknown.

Dimensions:

(in millimeters)

	Length	Width	Number of whorls
Holotype:	18.4	6.5	10.5
Paratype I:	14.4	5.0	10.0
Paratype II:	18.6	6.5	10.0
Paratype III:	13.5	5.5	8.0

(early whorls missing in all specimens listed above)

Type locality: Trawled off Punta de Juatinga, Lat. 23°22′ S., 48°28′ W., in 50 meters.

Repositories: Holotype, Stanford Univ. Paleo. Type Coll. no. 9738; Paratype I, Museu Nacional, Rio de Janeiro, no. Harvard; Paratype II, American Museum of Natural History, New York; Paratype III, Museu Nacional, Rio de Janeiro, no. 3117.

Discussion: This species is similar to *Epitonium fractum* Dall, 1927 but differs in having fewer costae on the body whorl, the costae never form spines or hooks at the shoulder angle, and also the whorls are less convex in outline. The new form is trawled together with *E. georgettina* (Kiener, 1839), from which it is easily separated by its smaller size and lower costae. A badly broken shell measured the maximum size of 25.7 mm in length, 9.1 mm in width.

This new species is dedicated to Dr. Maury Pinto de Oliveira, Brazilian malacologist.

Figure 5: *Epitonium mauryi*, holotype, Stanford Univ. Paleo. Type Coll. no. 9738. × 2.7. Recent, Rio de Janeiro.

ACKNOWLEDGMENTS

We wish to express our gratitude to Dr. Myra Keen for encouraging this work, critically reading the manuscript, and kindly helping in many ways. We thank Mr. Perfecto Mary, also of Stanford University, for the line drawings used here.

Provisional Classification of the Genus *Notocypraea* Schilder, 1927 (Cypraeidae)

BY

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There was always a great confusion concerning the classification of the so-called species and varieties which belong to the genus *Notocypraea* Schilder, 1927, restricted to the coasts of southern Australia and Tasmania. Even the most modern "reviews" by Griffiths (1961, 1962) are not satisfying, as he describes ten "species" in alphabetical order without indicating the essential characters which distinguish each from the other, so that identification by the aid of the photographs becomes difficult.

NAMES

The names established for genera, species, subspecies and "varieties" (nomenclatorially of subspecific rank) may be arranged chronologically as follows (|| designates preoccupied names not valid on account of prior homonyma):

(nameless species, pl. 13, fig. QQ) Gualtieri, 1742
(=*angustata* Gmelin)
Cypraea angustata Gmelin, 1791
Cypraea || *maculata* Perry, 1811

Cypraea piperita Gray, 1825
Cypraea || *castanea* Anderson, 1836
Cypraea (em.) *piperata* Catlow & Reeve, 1845
Cypraea pulicaria Reeve, 1846
Cypraea comptonii Gray, 1847
Cypraea bicolor Gaskoin, 1849 (not 1848)
Cypraea declivis Sowerby, 1870
Cypraea (err.) *pipitata* Brazier, 1882
Cypraea angustata var. *subcarnea* Beddome, 1896
Cypraea angustata var. *mayi* Beddome, 1898
Cypraea angustata var. *albata* Beddome, 1898
Cypraea angustata var. || *globosa* Vayssière, 1910
Erronea (*Stolida*) *angustata piperita* var. *reticulifera* Schilder, 1924
Cypraea piperita var. *leucochroa* Sullioti, 1924
Notocypraea (n. g.) Schilder, 1927; type: *piperita* Gray
Notocypraea bicolor emblema Iredale, 1931
Notocypraea piperita dissecta Iredale, 1931
Thelxinovum (n. g.) Iredale, 1931; type: *molleri* Iredale
Thelxinovum molleri Iredale, 1931
Notocypraea verconis Cotton & Godfrey, 1932
Notocypraea declivis occidentalis Iredale, 1935
Guttacypraea (n. g.) Iredale, 1935; type: *pulicaria* Reeve
Notocypraea (*Notocypraea*) *emblema* syn. (em.) *mölleri* Schilder, 1941
Guttacypraea euclia Steadman & Cotton, 1946
Guttacypraea pulicaria (var.) *candida* Coen, 1949
Notocypraea angustata (var.) *lentiginosa* Coen, 1949
(err.) *Thelixinovum* Allan, 1956; type *molleri* Iredale
Cypraea (*Notocypraea*) *wilkinsi* Griffiths, 1959
Cypraea (*Notocypraea*) *trenberthae* Trenberth, 1961
Notocypraea casta Schilder & Summers, 1963

Note: According to the International Rules of Zoological Nomenclature (1958), Art. 31 the name *comptonii* should be emended to *comptoni*, and according to Art. 32 *molleri* should be emended to *moelleri*, as this species was named after Capt. Möller [*sic*]; however, contrary to Art. 31, I do not recommend emending *verconis* to *vercoi*, though the latter name would not be preoccupied by *Zoila friendii vercoi* Schilder, 1930. The "emendation" of *piperita* to *piperata* is not justified.

NOMENCLATURE

The taxonomic arrangement of these cowries is rather difficult, especially for the following two reasons:

1. The genus *Notocypraea* is a relatively young one, so that the differentiation into clearly definable species and widely distributed geographical races has not yet been completed: for *N. jonesiana* (Tate, 1890) seems to be the only Pliocene *Notocypraea* (known from Victoria and Adelaide), while its Miocene ancestor *subregularis* Schilder, 1935 from the Balcombian of Victoria still belongs to the ancestral genus *Notoluponia* Schilder, 1935.

2. Griffiths (1962, p. 212) asserts a curious abnormality in the ontogeny of *Notocypraea*: it seems to be abbreviated by the absence of the veliger stage, so that young cowries hatch directly from the egg capsules. This process would favor the development of "local races" in restricted localities, as "the intermixture of genes caused by the long distances travelled by free-swimming larvae" would be suppressed.

Therefore, the views about the taxonomic value of species and "varieties" are very different: so, for instance, Verco (1918) regarded all *Notocypraea* as varieties of one species only (*angustata*), while Beddome (1898) had distinguished seven species in Tasmania; Iredale (1935) admitted eight species in the whole area inhabited by *Notocypraea*, and Griffiths (1962) ten species; in my last catalogue (Schilder, 1941) I admitted four real species, and four to five in the present paper.

Besides there are nomenclatorial difficulties: so, for instance, I cannot agree with Griffiths' views concerning the use of the specific name *piperita*, which he has submitted to the International Commission of Zoological Nomenclature (Griffiths, 1962 a), and I continue to adhere to my interpretation of *piperita* as explained in a previous paper (Schilder, 1961), because I have examined personally the type shells preserved in the British Museum (Natural History). The names *angustata* and *comptoni* have been erroneously interpreted as cowrie species living in other regions, viz. as *Luponia fuscodentata* (Gray, 1825) and *Erronea walkeri* (Sowerby, 1832), and therefore have been unnecessarily renamed *verconis* and *trenberthae* by Cotton & Godfrey, (1932) and Trenberth (1961) respectively. There are many other misidentifications made chiefly by Australian malacologists, e.g. the deep water *bicolor* (called *euclia* later on) has been mistaken for *pulicaria* by Verco, 1912 and Vayssière, 1923; and *casta*, a light whitish unspotted *comptoni* used to be called *albata* in Australian collections, a name established for a monstrosity of *angustata* suffused with heavy white callus.

ANIMALS

There are probably constant differences in the color of the animal, but though some of them have been described already a hundred years ago (Angas, 1865), our present knowledge is very poor and not sufficient for taxonomic arrangement.

The radula shows differences which far exceed the limits observed between real species of other cowrie genera. The median tooth shows three types with regard to its basal teeth:

1 They are rather closely set near the center of the base; GRIFFITHS (1962, pl. 4) figured this type in *Notocypraea pulicaria, N. bicolor* (called *"piperita"*), *N. euclia, N. wilkinsi,* and *N. occidentalis* ("species W"), but also in the large median of the holotype of *N. emblema*; in *N. dissecta* and in the young specimen called "species Y" these basal teeth are slightly more separated.

2 They are displaced to the corners of the median where they form oblique denticles in *Notocypraea comptoni, N. casta* (according to a personal communication by GRIFFITHS), *N. declivis* (according to VAYSSIÈRE, 1923) as well as in the "species Z" the median of which looks like a monstrosity.

3 They unite with the corners themselves so that they appear less distinct in *Notocypraea angustata* and *N. moelleri.*

Personal examination of some few radulae showed *Notocypraea reticulifera* (from Albany) to be like *N. bicolor* as figured by GRIFFITHS, while two *N. bicolor* (from Tumby Bay in the Spencer Gulf) show short broad basal teeth approaching each other as it is in *N. dissecta,* but they protrude behind like in *N. emblema*, and the plate itself is almost as oblong as in GRIFFITHS' "species Y". Oliviform *N. piperita* (*sensu* SCHILDER) from Albany agree with GRIFFITHS' *"comptonii"* as well as my *piperita* (Phillip Island) and my *trenberthae* (Tumby Bay), and as a radula of *"comptonii"* (from Victoria) preserved in the British Museum, but without a shell; an "*angustata*" (from Tasmania) preserved in the British Museum in the same way agrees with the latter and not with *angustata* of GRIFFITHS.

The admedians and laterals are tricuspid anteriorly in *Notocypraea reticulifera* (Albany), *N. euclia* (*"pulicaria"* VAYSSIÈRE, 1923), and *N. wilkinsi* (GRIFFITHS, 1959). In the five smallest specimens among eight oliviform *N. piperita* (Albany) the admedian exhibits four to five denticles on its anterior border, as it is in *N. piperita* (Phillip Island), *N. trenberthae* (Tumby Bay), *N. comptoni* (Victoria), and *N. declivis* (Tasmania: VAYSSIÈRE, 1923). Occasionally the laterals also may be adorned by more than three denticles in front.

These observations point to a great variability in the features of the radula, which has been noted also in other cowrie species {e. g. *Bistolida stolida* (LINNAEUS, 1758): median with or without basal teeth; *Staphylaea limacina* (LAMARCK, 1810): laterals long and slender or broadly hook-like}. Nevertheless the five species conchologically distinguished below may be characterized by the basal teeth of the median of the radula as follows:

1 Strong, conspicuous 2
- Obsolete, confluent with the corners .... *Notocypraea angustata*

2 Rather central .. *N. pulicaria, N. bicolor*
- Near to the corners *N. piperita, N. declivis*

SHELLS

The characters of the shell are also rather variable, so that extreme varieties become hardly distinguishable, if one compares each pair of adjacent species of the sequence *Notocypraea pulicaria, N. bicolor, N. piperita* and *N. angustata.* The great majority of rather typical specimens, however, is always well recognizable. Moreover, most species are separable into several "subspecies" of various degree (see below), which can be identified according to the following dichotomous key:

1 Fossula concave, projecting in its posterior half; teeth extremely fine; shell cylindrical, dorsum low; pale, with 4 narrow interrupted zones and well defined fulvous dots .... *Notocypraea pulicaria*
- Fossula shallow, projecting at most in its anterior half; teeth fine; shell oblong to ovate, dorsum raised, irregularly freckled if spotted at all .... (2)

2 Anterior edge of the fossula not connected with the interior wall of the dorsum; dorsum not humped, extremities produced, outer lip margined, basally narrow and convex, teeth short, fine, fossula and columellar sulcus often concave .... (3)
- Anterior edge of the fossula connected with the interior wall of the dorsum; dorsum humped, extremities short, outer lip less margined, broad (so that the aperture becomes more central) and flattened, labial teeth produced to ribs, columellar teeth slightly coarser; fossula and columellar sulcus reduced as well as the inner part of the anterior terminal ridge; dorsal zones absent to obsolete, terminal blotches conspicuous .... *Notocypraea* (*angustata*) (13)

3 Dorsum whitish, mostly freckled or reticulate with fulvous, 4 zones (if present) interrupted into large blotches, posterior zone also distinct, anterior terminal spots obsolete .... *Notocypraea bicolor* (4)
- Dorsum mostly fawn (though varying from white to dark purple), often with chestnut spots in its lateral parts, 4 zones narrow but less interrupted, the central pair being accentuated while the terminal zones become obsolete, anterior terminal spots conspicuous *Notocypraea piperita* (8)

4 Dorsal zones distinct, lateral spots dark ...... (5)
- Dorsal zones absent, lateral spots obsolete (pale to absent) .... (7)

5 Shell oblong, light, white with pale fulvous markings, dorsal zones narrow and distant ....
Notocypraea bicolor occidentalis

- Shell subpyriform, solid, pale flesh color with fulvous markings .... (6)

6 Dorsal zones narrow and distant, shell less solid
Notocypraea bicolor reticulifera

- Dorsal zones broad (the central pair often confluent), shell solid ....
Notocypraea bicolor bicolor

7 Shell subpyriform; lives in shallow waters ....
Notocypraea bicolor wilkinsi

- Shell very oblong; lives in deep waters ......
Notocypraea bicolor euclia

8 Shell oblong to subcylindrical, base less callous (9)

- Shell rather pyriform, attenuated in front .. (10)

9 Fossula rather projecting and concave; anterior extremity constricted ....
Notocypraea piperita dissecta

- Fossula less developed; anterior extremity dilated
Notocypraea piperita piperita

10 Margins spotted, dorsum zonate .... (11)

- Margins unspotted, dorsum inzonate, whitish ..
Notocypraea piperita casta

11 Shell rather slender and light, dorsal zones pale (the central pair often confluent), lateral spots fine, base mostly fulvous, convex .... (12)

- Shell broad, callous, dorsal zones conspicuous (central pair mostly disjunct), lateral spots coarser, base whitish, flattened ....
Notocypraea piperita mayi

12 Dorsum dark brown to purplish, base fuliginous
Notocypraea piperita trenberthae

- Dorsum fawn, base pale orange ....
Notocypraea piperita comptoni

13 Dorsum pale, closely freckled, lateral spots rather fine
Notocypraea (angustata) declivis

- Dorsum unspotted, lateral spots rather coarse ...
Notocypraea angustata (14)

14 Shell rather light, dorsum pale, mostly with 4 indistinct zones, base often pale flesh color ....
Notocypraea angustata moelleri

- Shell solid, dorsum chestnut to gray-brown, inzonate, base white ....
Notocypraea angustata angustata

ILLUSTRATIONS

Typical shells of the species and subspecies characterized above are represented by the following figures in Sowerby (1870) [S], Beddome (1898) [B], Allan (1956: bad and distorted) [A], and Griffiths (1961 [G¹] and 1962 [G²]):

	[S]	[B]	[A]	[G¹]	[G²]
Notocypraea					
pulicaria	290-291		2:35-36	31-32	45-46
occidentalis					57-59
					64-66
reticulifera					
bicolor	288-289	17-18	4: 7- 8	26-30	47-50
	533				
wilkinsi				33-35	60-63
euclia			4: 1- 2	18-20	34-36
dissecta			4:11-12	14-17	28-33
piperita	285-286		2:15-16	8	10-12
trenberthae	293			9	13
comptoni	294-295	15-16	(4:4a)	6	17
mayi		4- 7	4:3a	7	19-20
casta					21
declivis	328ˣ-329ˣ	12-14	4: 9-10	10-13	22-24
moelleri		(2??)	2:29-30	21-25	37-39
angustata	296-297	1	4:19-20	1-5	1-7

Besides: *N. subcarnea* [B] 8-10; *N. albata* [B] 11; N. *N. emblema* [A] 4:13-14.

QUANTITATIVE CHARACTERS

The following table has been calculated by Dr. Maria Schilder; it contains L = length of the shell in mm, BL =maximum breadth expressed in % of L, and the number of labial (= LT) and columellar (= CT) teeth reduced to shells of L = 25 mm (see Proc. Malac. Soc. London 23: 124; 1938). The figures taken from about 900 shells measured by us have been balanced with those given by Griffiths, 1962. The first figure designates the mean, the two figures added in parentheses express the variation of about 90% of the specimens (i. e. four times the standard deviation), thus excluding the rare extreme shells. One will observe a general increase in L and BL, but a decrease in LT and CT.

(see table, page 41)

DISTRIBUTION

The geographical range of the species and subspecies distinguished above is as follows (only reliable localities of specimens examined by us, or described or figured by other writers in a satisfactory way have been considered)

Notocypraea	
pulicaria	Rottnest Island to Flinders Bay
occidentalis	Cape Naturaliste to Cape Leeuwin
reticulifera	Flinders Bay to Esperance
bicolor	Fowlers Bay to Eden; Tasmania
wilkinsi	Victoria: Flinders to Liptrap
euclia	West of Eucla (deep water)
dissecta	Green Cape to Twofold Bay (deep water)

	L	BL	LT	CT
Notocypraea				
pulicaria	17 (15-20)	56 (53-59)	29 (26-31)	27 (24-31)
occidentalis	19 (16-23)	59 (56-62)	27 (24-29)	23 (20-25)
reticulifera	20 (17-25)	59 (56-63)	26 (24-28)	22 (19-25)
bicolor	22 (18-25)	60 (57-64)	26 (24-28)	22 (19-25)
wilkinsi	20 (17-24)	59 (54-62)	27 (25-29)	22 (20-25)
euclia	20 (17-24)	53 (51-55)	28 (26-30)	25 (23-27)
dissecta	20 (17-23)	56 (53-59)	28 (26-31)	23 (21-25)
piperita	21 (18-26)	60 (57-64)	25 (22-28)	21 (19-24)
trenberthae	24 (20-27)	59 (56-62)	24 (22-27)	21 (19-23)
comptoni	23 (19-27)	62 (59-66)	24 (21-27)	21 (19-24)
mayi	23 (20-27)	65 (61-68)	24 (22-27)	21 (19-24)
casta	24 (21-28)	62 (59-65)	24 (22-27)	19 (18-22)
declivis	24 (20-27)	66 (63-69)	24 (22-27)	19 (17-22)
moelleri	24 (20-27)	62 (58-65)	26 (23-28)	20 (19-23)
angustata	26 (22-30)	67 (64-71)	24 (21-27)	19 (17-22)

piperita	Cape Leeuwin to Eden
trenberthae	Spencer Gulf: Tumby Bay (locally)
comptoni	Hopetown to Malacoota; Tasmania
mayi	Port Mac Donnell to Malacoota; Tasmania
casta	Port Mac Donnell (locally)
declivis	Port Mac Donnell to Lorne; Tasmania
moelleri	Lakes Entrance to Eden (deep water)
angustata	Port Drummond to Eden; Tasmania

Therefore, *Notocypraea pulicaria* is almost restricted to the southern west coast of Australia, with the center at Cape Naturaliste. - Its range approximately coincides with that of *N. occidentalis* which is connected both geographically and morphologically by *N. reticulifera* (western south coast) with the typical *N. bicolor* (eastern south coast and Tasmania); *N. wilkinsi* seems to be at most a local mutant from Victoria, and *N. euclia* is the deep water representant of *N. bicolor* in the Great Australian Bight. - The third species, *N. piperita,* is not represented on the west coast, but otherwise its range is similar to that of *N. bicolor;* however, the slender subspecies do not reach Tasmania (the typical *N. piperita* occurs from south-western Australia to Eden, and is replaced by *N. dissecta* in the deep waters of southern New South Wales), while the pyriform *N. comptoni* and *N. mayi* reach Tasmania (the latter evidently does not spread west of Victoria); *N. trenberthae* and *N. casta* seem to be local mutants living in restricted areas only. - The fourth species, *N. angustata,* evidently originated in the Bass Strait: while *N. declivis* seems to be restricted to this area, *N. angustata* occurs sporadically as far as to the Spencer Gulf and Eden, and is replaced by *N. moelleri* in the deep waters of southern New South Wales.

TAXONOMY

The *Notocypraea* characterized in the dichotomous key should be comprised into four or five species:

1. *Notocypraea pulicaria,* which is geographically the only species restricted to less cold waters, and morphologically the only well separable species among its allies, showing characters least aberrant from other Cypraeovulinae; nevertheless I do not recommend to separate it as a monotypical subgenus *Guttacypraea;*

2. *Notocypraea bicolor,* which approaches it in some respects and evidently originated farther west along the south coast, than

3. *Notocypraea piperita* did, which approaches especially in color the most eastern species,

4. *Notocypraea angustata* (from which *N. declivis* possibly can be separated as a more primitive species): this species is restricted to the coldest regions around the Bass Strait and shows the most unusual features (fossula!) so that it should be regarded as the last extreme offspring of the phylogenetic branch called *Notocypraea.*

Therefore, this sequence of species seems to indicate the way of evolution of the genus; it is confirmed by other units named in the key above, which partially seem to be connecting links between the typical representatives of the four species.

The other eleven taxa should be classified as subspecies according to the International Rules of Zoological Nomenclature, though their significance in evolution is quite unequal: but this essential fact has not been considered by the Rules so that all units must be treated formally as equal.

There are only three taxa forming a cline, which are separated geographically so well that they should be

called geographical (chorological) races: *occidentalis, reticulifera,* and *bicolor* (the former is more separated morphologically than the two last named each from the other). In other pairs excluding each member from the other, viz. *piperita* - *dissecta* and *angustata* - *moelleri* there are differences in the depth of the inhabited waters; *euclia* is a deep water "race" of *reticulifera* inhabiting the adjacent shores. The relation between *piperita - comptoni - mayi* is less evident: as their geographical distribution is greatly overlapping (though differing slightly in border areas) they look like an ecological cline. Other "subspecies" (for which the unofficial term "infraspecies" would be more adequate) seem to represent local mutants which recently arose so that there was no time to spread ("no veliger"!): *wilkinsi* from *bicolor; trenberthae* and *casta* from *comptoni.* Possibly the status of *declivis* may be similar, as it agrees with *angustata* in all essential characters except the freckled dorsum; but it has spread to a large area within that of *angustata,* and there are few intermediates so so that one could treat *declivis* also as a fifth species, especially if the differences in the radula should be proved.

The other names mentioned above in the chronological list should be regarded as synonyms as they designate individual modifications at most: *subcarnea* and || *globosa* refer to *angustata* pathologically suffused with yellowish enamel, and *albata* likewise with white enamel so that the lateral spots become hidden and the base very callous; *leucochroa* is a name for the "albinism" of "*piperita* (SOLANDER) GRAY", therefore it may be a *piperita* the dorsum of which is white instead of fawn (I have seen such a zonate white shell with spotted margins), or even - if it should be interpreted as pure white - a prior synonym of *casta*; *candida,* however, probably is an albinotic *pulicaria* or based on a beach worn shell of this species; *emblema* seems to be identical with *moelleri* in spite of the differences in radula; *lentiginosa* (not preoccupied!) is an absolute synonym of *declivis,* as well as || *maculata,* || *castanea* and *verconis* are synonyms of *angustata.*

CLASSIFICATION

The *Notocypraea* discussed above can be arranged in the following list which shows the evolutionary trend (s = subspecies and i = infraspecies limited c = chorologically (geographically) or e = ecologically; ir = restricted mutants; v = individual variants; the = sign indicates important synonyma, || designates preoccupied names, / denotes authors who used the name not in the original meaning).

Notocypraea SCHILDER, 1927
type: *piperita* GRAY
= *Thelxinovum* IREDALE, 1931, type: *moelleri* IREDALE
= *Guttacypraea* IREDALE, 1935, type: *pulicaria* REEVE

pulicaria REEVE, 1846
= *candida* COEN, 1949

bicolor GASKOIN, 1849
sc *occidentalis* IREDALE, 1935
sc *reticulifera* SCHILDER, 1924
ie *euclia* STEADMAN & COTTON, 1946
= *pulicaria* /VERCO, 1912, VAYSSIÈRE, 1923
sc *bicolor* GASKOIN, 1849
= *piperita* /SOWERBY, 1832 /GRIFFITHS, 1961, 1962
ir *wilkinsi* GRIFFITHS, 1959

piperita GRAY, 1825
se *piperita* GRAY, 1825; GASKOIN, 1849
= *comptoni* /GRIFFITHS, 1961, 1962
ie *dissecta* IREDALE, 1931
se *comptoni* (em.) GRAY, 1847
ir *trenberthae* TRENBERTH, 1961
ir *casta* SCHILDER & SUMMERS, 1963
= *comptoni* var./COTTON & GODFREY, 1932
?= *leucochroa* SULLIOTI, 1924
se *mayi* BEDDOME, 1898

declivis SOWERBY, 1870 (ir of *angustata ?*)
= *angustata* /GRAY, 1828
= *lentiginosa* COEN, 1949

angustata GMELIN, 1791; GRAY, 1825
= || *maculata* PERRY, 1811
= || *castanea* ANDERSON, 1836
= *subcarnea* /SCHILDER, 1927
= *bicolor* /IREDALE, 1931
= *verconis* COTTON & GODFREY, 1932
v *subcarnea* BEDDOME, 1896, 1898
= || *globosa* VAYSSIÈRE, 1910
v *albata* BEDDOME, 1898
ie *moelleri* (em.) IREDALE, 1931
= *emblema* IREDALE, 1931

ACKNOWLEDGMENTS

The present study is based mainly on several hundred specimens with exact locality data, sent to me chiefly by Dr. C. M. Burgess, Col. R. J. Griffiths, Mr. Ray Summers, and Mr. B. R. Wilson (they had been collected in part by Mrs. Bowman, Constantine, Crabbe, Lang, Marsh and Trenberth). I am much obliged to these malacologists for allowing me to keep about 600 specimens in

my collection for permanent study; this number is about six times as large as the sum total of all *Notocypraea* which I could study in the public and private collections of almost all countries of Europe. Most specimens came from Victoria and West Australia, some interesting shells also from South Australia, whereas my personal knowledge of specimens from Tasmania and New South Wales is still rather limited.

LITERATURE CITED

ALLAN, JOYCE

1956. Cowry shells of world seas. Georgian House, Melbourne. i - x;; pp. 1 - 170; plts. 1 - 15.

BEDDOME, C. E.

1898. Notes on species of *Cypraea* inhabiting the shores of Tasmania. Proc. Linn. Soc. N. S. Wales, 22: 564 - 576; plt. 31.

GRIFFITHS, R. JOHN

1961. *Notocypraea* — The shells. The Cowry 1 (2): 10 - 14 [= 26 - 30]; plts. 3 - 4.

1962. A review of the Cypraeidae genus *Notocypraea*. Mem. Nat. Mus. Victoria, no. 25: 211 - 231; 4 plts.

1962 a. *Cypraea piperita* GRAY, 1825 (Gastropoda); proposed suppression under the plenary powers. Z. N. (S.) 1510. Bull. Zool. Nomencl., 19 (5): 317 - 322.

SCHILDER, FRANZ ALFRED

1961. Nachträge zum Katalog der Cypraeacea von 1941. Arch. Moll. 90 (4 - 6): 145 - 153

SOWERBY, GEORGE BRETTINGHAM (second of name)

1870. *Cypraea*. In Thes. Conch., 4: 58 pp.; 37 plts.

The Egg Capsule and Young of *Beringius eyerdami* SMITH

(Neptuneidae)

BY

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(Plate 7)

Beringius eyerdami SMITH, 1959, though only recently discovered and described, is widely distributed along the coast of British Columbia. I now have specimens from seven localities between Swiftsure Light in the entrance to Juan de Fuca Strait and Hakai Pass near Calvert Island. More specimens have been secured in Hecate Strait than in any other region. Here it occurs at depths of about 50 fathoms on relatively smooth bottoms of sandy mud with some gravel and shell. Associated with it here are *Neptunea lirata* (GMELIN, 1791), *N. smirnia* (DALL, 1919) and an unnamed species of *Neptunea* that is presently under study by Allyn Smith of the California Academy of Sciences.

On a voyage that lasted from April 8 to 13, 1962, a trawler operating on Goose Island Banks, Hecate Strait, B. C., brought up in its net three specimens of *Beringius eyerdami* and, along with them, a valve of *Pecten caurinus* to which were attached three egg capsules of a type new to me. While the mere association of the capsules with the adult *B. eyerdami* would not in itself serve to identify them, a close study of the young in the capsules has convinced me that they are that species.

The capsules are larger than any reported so far in this group of mollusks and differ also in some other features. Each capsule is cemented to the substrate by a double flap-like extension of its outer material arising from its long edge. Each is a thin pouch-like vessel placed so as to overlap the next one (Plate 7, fig. 1). The capsules measured wet were 42.2 mm by 32.6 mm; 41.5 mm by 31 mm and 41 mm by 38 mm. When dry, corresponding measurements are 38 by 25, 38 by 24, and 35 by 28 millimeters.

The outer surfaces of the capsules are of an off-white colour, and when wet appear very pale yellow. Each capsule is a complete envelope within an envelope, the two differing in structure but of approximately equal thickness. The inner envelope, however, is much tougher, more difficult to cut than the outer, and when wet, is strongly resistant to tearing. Two of the capsules were intact, and in these the edges were firmly closed all

round, with no visible trace of a suture. The one empty capsule is ruptured along and immediately below the free edge. From this edge projects a tuft of coarse yellow fibres.

The outer element of the capsule is about 0.15 mm in thickness, smooth, and, at 50 × magnification, it reveals no structure. Beneath this surface is a corneous layer bearing on its inner surface fine ridges parallel and in the long axis of the capsule. These are irregularly spaced and have the appearance of hairs cemented to the surface. The most distinctive feature of the capsule is that the entire space between the inner and outer envelopes is packed with long slender fibres strongly yellow in colour. These are arranged in the long axis of the structure. Many of them are attached to the inner surface of the outer capsule and appear to be continuous with it and of the same material. The longer threads are about 40 mm in length and most are free at each end.

The outer surface of the inner capsule bears many delicate laminae, again in the long axis of the capsule. They differ in height and spacing but average 4½ laminae per millimeter. Some are plain, others sinuous. Many of the interenvelope fibres appear to arise as lamellae detached from this inner capsule. The surface lining the brood chamber is smoothly finished and without apparent structural detail. - Young: Each of the complete capsules contains 5 young, two of the ten were crushed and could not be measured. The first 5 listed below were capsule mates as were the last 3. Those 12 mm or more in length bear 3 whorls, the others about 2½ whorls (Plate 7, fig. 2). In each the nuclear whorls originate in an apical concretion and increase rapidly in size. For the first half of the first whorl the suture is deeply channeled, beyond that it is normal for the adult of the species. At 2½ whorls the deep narrow spiral grooves and intervening wide rounded ridges of the adult sculpture are clearly apparent. The nuclear whorls are covered in a delicate cuticle that wrinkles on drying.

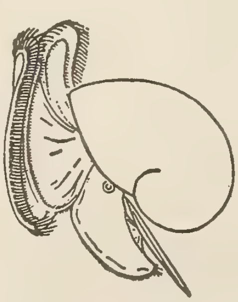
The structure of the apical concretion of the first nuclear whorl in these young differs importantly from that in capsular or newly emerged young of *Neptunea tabulata* BAIRD, 1863, *N. smirnia* (DALL, 1919), *N. phoenicea* (DALL, 1919), *N. lirata,* and *N. pribiloffensis* (DALL, 1919). In all these the apex is swollen and stud-like and is not bounded internally by a deep sutural groove. In *Beringius eyerdami,* on the other hand, it is smaller, discrete, and clearly separated from the first whorl by a deep sutural groove. This may prove to be a generic characteristic.

Table 1

Dimensions of capsule young of *Beringius eyerdami*
(measurements in millimeters)

Height	Aperture length	Width of first Nuclear Whorl	Width of second Nuclear Whorl
9.95	4.4	3.5	4.6
12.0	5.2	3.7	4.5
11.0	4.75	3.55	4.2
9.2	4.4	3.7	4.9
9.4	4.85	3.5	5.0
12.5	5.6	3.9	4.6
11.6	4.9	4.1	4.7
10.9	5.4	4.0	4.9

A comparison of the shell thickness of the nuclear whorls at this stage with the thickness of the nuclear whorls attached to the adult shell reveals that a great increase in calcification of the nucleus takes place after the young leave the capsule. It also suggests that the whorls on the adult shell that are usually referred to as the nucleus include one or more post nuclear whorls that have lost their distinctive sculpture. In the present specimens two to two and a half whorls constitute the true nucleus.



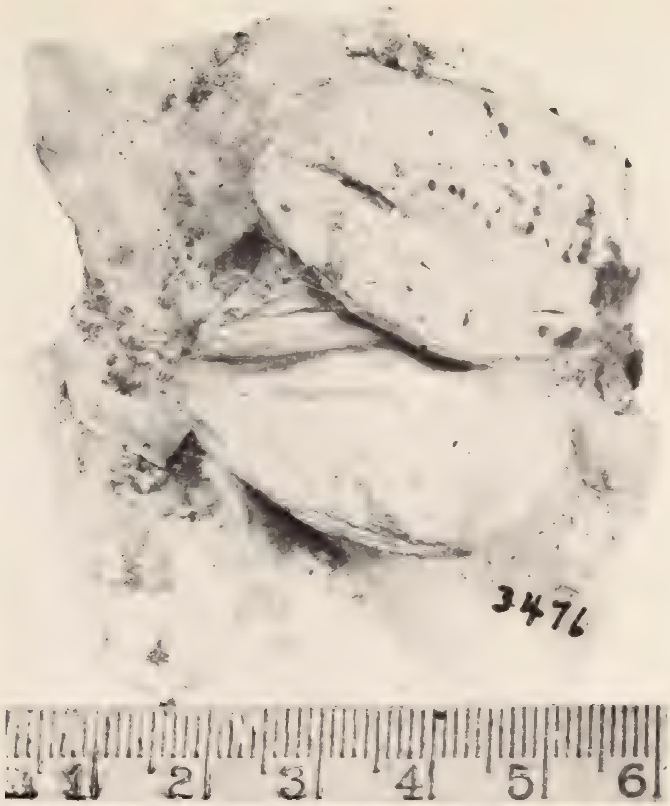


Figure 1: Two Capsules *in situ*.

Figure 2: Capsule opened to show young
and abundant interenvelope "hair".

Notes on the Peculiar Egg Laying Habit of an Antarctic Prosobranch (Mollusca : Gastropoda)

BY

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(1 Text figure)

Many marine invertebrates of colder waters, including those of the deep sea, produce large yolky eggs, and these in turn produce rather large, non-pelagic larval stages. Among the mysteries of deep-sea biology is the means of reproduction of pycnogonids of the genus *Colossendeis*. There are perhaps thirty species in this genus, among them the largest known pycnogonids. Yet no specimen of the hundreds so far collected has been observed in the reproductive state, and the nature of the eggs of this genus and of the related polymerous forms (*Decolopoda, Pentacolossendeis,* and *Dodecolopoda*) is unknown. For this reason close attention is paid to various objects adhering to these pycnogonids.

In examining the extensive collections of pycnogonids from Antarctic waters, several specimens were observed with rows of eggs, slightly more than a millimeter in in diameter, adhering to the legs. These appear to be the eggs of some prosobranch mollusk (Figure 1). These eggs are usually on the ventral surface of the long joints (femur and tibia) of the legs, but in one specimen they were on the ventral surface of the body. These positions are apparently out of reach of the terminal segments of the accessory egg-carrying legs (ovigers), which are used by those pycnogonids to groom themselves. Since the four short terminal segments form a sort of shepherd's crook that is applied to the dorsal surface of the long legs, it would appear that a narrow area of the ventral surface of the legs may not be reached in cleaning. For this reason it cannot be assumed that the pattern of a single or double row of eggs along the leg is the characteristic form of the egg mass of the mollusk.

These eggs were observed on three specimens of *Colossendeis megalonyx* Hoek, 1881, a common and widely distributed Antarctic species. This is a moderately sized *Colossendeis,* attaining a span of about six inches. The specimens were from Eltanin stations 410 (61°18′ to 61°19′30″ S; 56°08′30″ to 56°10′12″ W; 120 to 131 fathoms, December 31, 1962), and 437 (62°49′36″ to 62°50′30″ S; 60°40′ to 60°34′42″ W; 146 to 170 fathoms, January 9, 1963).

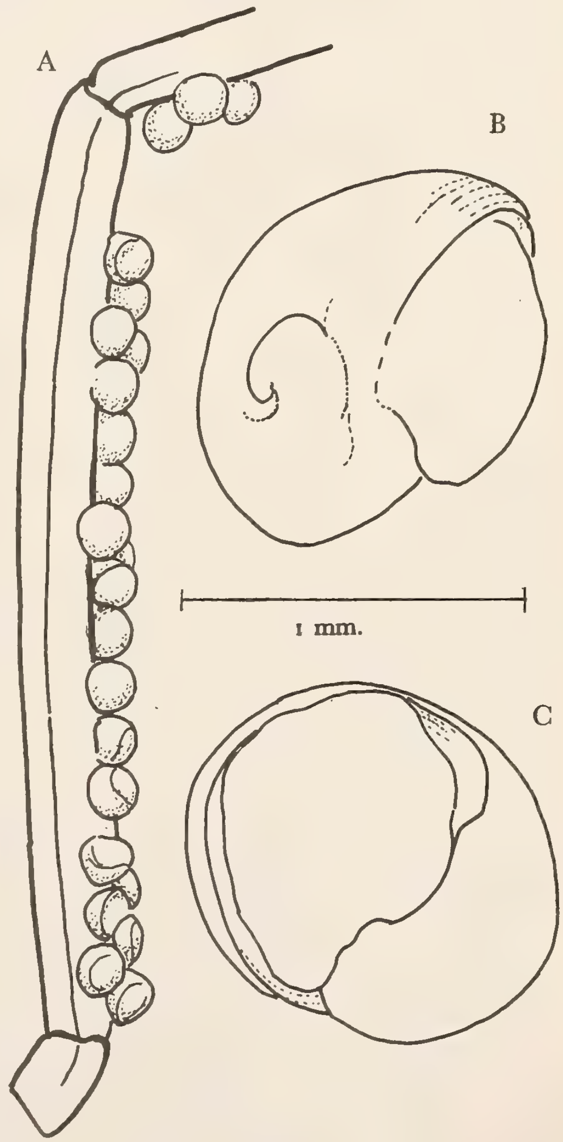

Figure 1: A. Coxa, femur and part of tibia of a specimen of *Colossendeis megalonyx,* showing arrangement of egg capsules; B - C. Views of embryo removed from capsule.

Long legged pycnogonids have been observed to walk about in a somewhat unstable manner, and their high ratio of surface to volume makes it easy for currents to move them about. On at least one occasion deep sea pycnogonids of this genus were observed floating near the bottom during a bathyscaphe dive (T. MONOD, 1954, Bathyfolages, p. 167). It would appear that the dispersal of pycnogonids is probably easier than that of shelled gastropods, and it is obvious that in this example at least the pycnogonid is a potential means for dispersion beyond the immediate site of egg deposition of at least one species of Antarctic mollusk.

Ten New Species of Typhinae

(Gastropoda: Muricidae)

BY

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(Plates 8 to 11; 3 Textfigures)

IN THE TWENTY YEARS since a review of the Typhinae was published (KEEN, 1944), much new information has accumulated. Authors have described a number of species that modify or add to the distributional picture then drawn up, and the study of fresh specimens and better material has indicated the need of another revision. Because, however, of a prospect for first-hand study of type material in certain European collections, this is being postponed for the time being. To put on record the undescribed forms presently before us seems desirable, in the hope that this stimulus will bring to light other unrecorded information collectors may have that would be useful in our projected review of the entire subfamily.

New interpretations of typhine morphology have been expressed by FLEMING (1962) and VELLA (1961). We shall reserve a more extended discussion of these for the proposed revisional work. VELLA, for example, would consider that most of the new species described herein have 4.2 "growth-steps" or varices per whorl, for as there is an offset of each varix below the one on the whorl preceding, it usually requires two complete turns for a varix to fall immediately below an earlier one. We continue, however, in the interest of simplicity, to describe such shells as having 4 varices per whorl, aware that the precise number may be any fraction between 4.0 and 4.9.

Typhis (Typhina) imperialis KEEN & CAMPBELL, spec. nov.

(Plate 8, figures 1 to 4)

Shell of moderate size, biconic, spire somewhat elevated; teleoconch of five whorls; protoconch of two whorls; nucleus small, flattened, in a central position, gradually expanding, with rounded whorls; varices four per whorl, a single spine at the shoulder curves dorsally and medially, remaining free from the preceding whorl; outer lip narrow and foliated with four or five crenulations between the shoulder and the anterior canal; varices thin, convex; shoulders acute, with a suture between the tip of the tube and the succeeding varix; suture distinct, moderately deep; tubes stout, arising about midway between varices, directed dorsally, with a decided adapical curve (see Table 1 for tube angles); aperture oval, with produced peristome flaring at margin to form

a secondary varix; siphonal fasciole with remnants of earlier canals; umbilical region not deeply grooved or perforate; anterior canal long, widened, closed, with slight bend to right and a noticeable fin-like spur on the labial side.

Type Material: Holotype at present is in the Akibumi Teramachi collection, Kyoto, Japan. The paratype is in the Stanford Univ. Paleo. Type Coll. no. 9727. Exact replicas of the holotype have been prepared in natural color out of acrylic plastic. One is on deposit in the Stanford Univ. Paleo. Type Coll. no. 9728. As others are prepared they will be distributed to the major repositories.

Type Locality: Holotype and paratype were trawled off Tosa, Japan in approximately 200 m. Lat. 33° 20′ N; Long. 133° 40′ E.

Age: Recent.

Dimensions: Height 16.5 mm, maximum diameter 10.2 mm (holotype).
Height 16.2 mm, maximum diameter 9.8 mm (paratype).

Remarks: This deep-water species has a close affinity to the Australian species *Typhis* (*Typhina*) *yatesi* CROSSE & FISCHER, 1865 but is distinguished by a different angle of exit of the tubes, more convex body whorl, with a decidedly contracted base, and narrower anterior canal.

Among the Japanese typhine fauna *Typhis imperialis* spec. nov. belongs in a compact group that includes *T.* (*Typhina*) *montfortii* A. ADAMS, 1863[1]; *T.* (*Typhina*) *tosaensis* AZUMA, 1960 represented by a single specimen, the holotype, that was trawled in excess of 200 m off Tosa, Japan (this species is also the type species for *Monstrotyphis*); and *T.* (*Typhina*) *teramachii* spec. nov. trawled off Kii, Japan in more than 100 m and also known from only the holotype.

[1] Mr. Teramachi estimates there are less than a dozen specimens known; he kindly gave us one beautiful specimen measuring 17.2 mm by 6.5 mm that was trawled in 60 m off Kii, Japan (see Plate 8, figures 5 to 7).

The similarities and differences can be summarized best in the form of a table that includes only the more obvious points.

The protoconchs of all five species have the same general form - an eccentric nucleus followed by $1\frac{1}{4}$ to $1\frac{1}{2}$ smooth, round, gradually expanding whorls.

Tube angles on a number of species have been measured and compared and it was found that there is rather wide variation between species belonging to the same group, but within a given species minimal variation in the angle of tube exit was noted. At the present time it is considered that these angles have limited systematic value primarily on a specific level. One example of the value of the angle of tube exit is the subgenus *Indotyphis* KEEN, 1944 in which the last tube is bent ventrally and soldered to the succeeding varix. For the sake of comparison, two of the tube angles are tabulated (Table 1) for each of the five species. These are more easily measured from photographs than using the actual shell because one is then working with a flat surface and the shell picture can be enlarged, increasing the accuracy of the measurement. For the "vertical angle" the shell is oriented with the aperture facing left, and the angle is measured between the long axis of the tube near the point of exit and the edge of plane that transects the shell at mid-aperture level (this is at a right angle to the shell's spiral axis). To determine the "dorsal angle" the shell is viewed from the "top," that is, the apex; the angle is measured between the long axis of the tube near the point of exit and a line drawn across, parallel with the edge of the aperture. The relationship between the tube and aperture remains constant.

Table 1

Species	Shell shape	Tube angles[1] Vertical	Dorsal	Varices (excl. shoulder spine)	Varical shoulder spine	Anterior canal
Typhis imperialis spec. nov.	Biconic	24°	84°	4 crenulations	Fluted; curved dorsally	Widened, a fluted spine present
T. montfortii A. ADAMS, 1863	Narrowly biconic	61°	47°	4 crenulations	Almost closed; vertical	Long, narrow, smooth
T. teramachii spec. nov.	Fusiform	33°	77°	8 crenulations	Closed; recurved ventrally	Long, narrow, smooth
T. tosaensis AZUMA, 1960	Markedly fusiform	ca. 60°	ca. 30°	4 recurved spines	Long, narrow closed, recurved	Long, narrow, a closed spine present
T. yatesi CROSSE & FISCHER, 1865	Biconic	25°	80°	4-5 crenulations	Partially closed, recurved ventrally	Widened, a fluted spine present

[1] see text

It becomes evident for reliability that tubes measured in a series of shells of the same or different species must be at the same relative stage of development. Ideally this means the last tube in adult shells of the same relative size or age and number of whorls. This was the case for the measurements in Table 1.

Typhis (Typhina) teramachii Keen & Campbell, spec. nov.

(Plate 8, figures 9 to 11)

Shell of moderate size, elongate; spire markedly elevated; teleoconch of five whorls; protoconch of $1\frac{3}{4}$ whorls, subcylindrical, gradually expanding, forming rounded whorls; nucleus eccentric and smooth; varices four per whorl, with a single spine at the shoulder which is trough-shaped, closed and recurved; varices thin, convex, and free from preceding whorl; lip narrow and foliated with eight forward curving crenulations; shoulder high on spire whorls, acute; periphery moderately contracted to form deep suture; carina between tip of tube and succeeding varix small; tubes long, slender, with a slight bend toward base, steeply inclined toward apex and obliquely to the rear, origin about midway between varices but exit closer to preceding varix (see Table 1 for tube angles); aperture oval, with a produced peristome that expands at margin, forming a secondary varix; siphonal fasciole with remnants of previous anterior canals; anterior canal very long, narrow, closed throughout, with a slight dorsal curve.

Type Material: Holotype at present is in the Akibumi Teramachi collection, Kyoto, Japan. Exact replicas of the holotype have been prepared in white acrylic plastic and one is on deposit in the Stanford Univ. Paleo. Type Coll., no. 9729. As others are prepared they will be distributed among several major institutions.

Type Locality: Trawled off Kii, Japan in more than 100 m. Holotype only specimen known. Lat. 33° 48′ N; Long. 134° 53′ E.

Age: Recent.

Dimensions: Height 20.7 mm, maximum diameter 8.3 mm (holotype).

Remarks: *Typhis teramachii* spec. nov. has all the features of *Typhina* in a narrowed interpretation based on *T.* (*Typhina*) *belcheri* Broderip, 1833. It differs from that species by being considerably more fusiform, with different tube morphology. Overall sculpture is that of *T.* (*Typhina*) *montfortii* A. Adams, 1863, a more biconic Recent Japanese species with tubes directed decidedly more apically and radially (see Table 1). A species similar in shape and laxness of coiling is the Recent Japanese form *T.* (*Typhina*) *tosaensis* Azuma, 1960, but this species has four prominent spines on the outer lip, one of which is at the shoulder, and a long, narrow, curving spur on the anterior canal.

It is likely that *Typhina* originated in the Australian area, the oldest record being *Typhis* (*Typhina*) *maccoyi* Tenison-Woods, 1876[2] (see Plate 8, figure 8) from the Janjukian (Oligocene), it is not surprising to find a similar loosely-coiled, elongate form in the Australian Tertiary, *T.* (*Typhina*) *disjunctus* Tate, 1888 (see Plate 8, figure 12) from the Balcombian (lower Miocene).

We take pleasure in naming this species in honor of Mr. Akibumi Teramachi, a well known Japanese collector who has been responsible for the discovery of many new and rare Japanese shells and has been very generous in sharing material.

Typhis (Typhisopsis) clarki Keen & Campbell, spec. nov.

(Plate 9, figures 15, 19 and 23)

Shell of medium size, light brown to creamy white, lighter on the parts of the lip varix face above and below the apertural opening; teleoconch whorls five or more; apex not well preserved on any specimens in the type lot

[2] Some authors prefer to retain this species in *Typhis s. s.* because of the nature of the varical spines, but since it has features of both groups we have chosen to place it in *Typhina*, recognizing that it may represent a transition stage.

Explanation of Plate 8

Figure 1: *Typhis* (*Typhina*) *imperialis* Keen & Campbell, spec. nov. Ventral view of holotype. × 2.7.
Figure 2: Lateral view; Figure 3: Apical view. Figure 4: Paratype S U P T C no. 9727 × 2.75.
Figure 5: *Typhis* (*Typhina*) *montfortii* A. Adams, 1863. (off Kii, Japan, 60 m). Ventral view. × 2.6.
Figure 6: Lateral view. Figure 7: Apical view.
Figure 8: *Typhis* (*Typhina*) *maccoyi* Tenison-Woods, 1876. (Manyung Rocks, Victoria, Australia; Oligocene?) Ventral view. × 2.0.
Figure 9: *Typhis* (*Typhina*) *teramachii* Keen & Campbell, spec. nov. Ventral view of holotype ×2.2.
Figure 10: Lateral view. Figure 11: Apical view.
Figure 12: *Typhis* (*Typhina*) *disjuncta* Tate, 1888. Ventral view. (Balcombe River, Australia; lower Miocene). × 3.

1 2 3 4

5 6 7 8

9 10 11 12

photography: G. BRUCE CAMPBELL

but apparently of $1\frac{1}{2}$ smooth turns; varices 4 per whorl; spiral sculpture weak but showing as festooning along the outer part of the lip varix; suture irregular, whorls excavated above the periphery to form a concave platform behind each remnant of a previous varix; tubes brown, long, slender, each tube soldered to the downward-sloping remnant of a previous varix-top or callus pad; anterior canal sealed, ending in a brown tube that is open at its tip.

Type Material: Stanford Univ. Paleo. Type Coll. no. 9724 (holotype), 9725 (paratype); California Academy of Sciences; United States National Museum.

Type Locality: Venado Island, Panama Bay; intertidally, at a — 3.0 tide. Collected by Walter D. Clark, March 1946. Lat. 8° 55′ N; Long. 79° 32′ W.

Age: Recent.

Dimensions: Holotype, height 20 mm, diameter 12 mm. Five paratypes ranging in size from height 24 mm, diameter 12 mm in the largest to height 16 mm, diameter 8 mm in the smallest, an immature specimen.

Additional Material: Two specimens from the Panama Bay area are in the collection of E. W. Ulrich; another is in the collection of John Q. and Rose Burch; one is in the Stanford University collection, a beach shell taken by Dr. James Zetek. A juvenile specimen collected at Mazatlán, Mexico, by James McLean in 1962 seems referable to this species because of its brown tubes.

Remarks: The quadrate profile of this shell has led to the identification of it as *Typhis quadratus* HINDS, 1843, in collections. Study of available evidence on the type material of *T. quadratus* convinces us that this is not a good species, that it must fall as a synonym of *T. coronatus* BRODERIP, 1833, representing only a stage of growth. *Typhis coronatus* is the type of the subgenus *Typhisopsis* which, like *Talityphis,* has very wide varices and has the tube forming immediately after the completion of a varix. In *Typhisopsis* the tube actually lies against the upper part or callus pad of the varix (see textfigure 1 for illustration of this term), and the varix remnant serves as a buttress for the base of the tube. The anterior canal area is wider in *Typhisopsis* than in *Talityphis.* Although *T. clarki* in some respects resembles certain species of *Talityphis,* it shares with *T. coronatus* the attachment of the tube to the preceding varix-remnant and the wide anterior canal. The part of the varix above the aperture (the callus pad) slopes downward at a steeper angle than in *T. coronatus,* and the spines on the varix shoulders are less recurved. The brown coloration of the tubes and the brown anterior tip to the canal are distinctive of *T. (T.) clarki*; so also is the lack of spiral sculpture.

The specific name is chosen in recognition of the work done by Mr. Walter D. Clark of Palatka, Florida, who, during the years of World War II, was stationed in Panama. Because of his collecting zeal and his generosity, a number of collections are the richer.

Typhis (Talityphis) precursor KEEN & CAMPBELL, spec. nov.

(Plate 9, figures 14, 18, 21 and 22)

Shell large, exceptionally sturdy, with massive tubes and ridge-like varices; teleoconch whorls 5, spire relatively high; varices and tubes 4 per whorl; pad above aperture a little narrower than the outer lip portion of the varix; sculpture almost entirely axial, with weak spiral lines showing only on the face of the outer lip varix, which is festooned slightly by about 6 spiral lines; aperture relatively large, its margin free and entire, standing upward as an oval rim; anterior canal completely sealed along the apertural face, open at end.

Type Material: Univ. Calif. Dept. Paleo. Type Coll. no. 15083 (holotype); paratypes, nos. 15084-15088. One hypotype (? or paratype) in the collection of Dr. Axel A. Olsson.

Type Locality: Univ. Calif. loc. S-8012, on the South American coast 6 km west of Puerto Colombia, Dept. Atlántico, Colombia. Collected by Max Steineke for Standard Oil Company. (Holotype and 3 paratypes). Lat. 11° 03′ N; Long. 75° 00′ W.

Other Localities: Univ. Calif. loc. S-8068, 500 m west of Puerto Colombia, Dept. Atlántico, Colombia. Max Steineke, collector. (Two specimens, regarded as paratypes because of the proximity of the collecting locality to the locality of the holotype). One specimen from "Near Puerto Colombia," collected by Dr. A. A. Olsson should probably also be regarded as a paratype rather than a hypotype, as it is evidently from the same outcrop section.

Age: Horizon - Las Perdices shales, upper Oligocene.

Dimensions (in millimeters):

	length	width
Holotype	47.5	27.8
Paratype I	41	27
Paratype II	40	25
Paratype III	37	23
Paratype IV	42	29 (loc. S-8068)
Paratype V	40.5	21 (loc. S-8068)
Hypotype	49	32

Discussion: In form, this is nearest to *Typhis (Talityphis) pterinus* GARDNER, 1936, which has a similarly high spire. However, *T. precursor* averages more than twice as large, for the type of *T. pterinus* is only 20 mm in length. Spiral sculpture is fairly strong in *T. pterinus,* and the

varices are not so ridge-like and massive. The stratigraphic horizon from which the type lot of *T. precursor* came, Las Perdices shale, is generally accepted as correlative with the Aquitanian Stage of Europe; whether this is upper Oligocene or lower Miocene in age is, however, a matter of debate among stratigraphers. Whatever the decision, this new species extends the known range of *Talityphis* downward in time from the previous occurrences in the lower to middle Miocene Round Mountain silt (Temblor formation) of California and the middle Miocene Shoal River formation (Alum Bluff group) of Florida. At the time the specimens were first noted as new by one of us (KEEN, in 1943), the available evidence seemed to suggest an even greater age; therefore, description was postponed until Dr. J. Wyatt Durham, who was then working in Colombia, could make a field study of the area. His report (letter dated December 20, 1943) cleared the way for description, but difficulties of publication during the World War II years and a busy schedule since has made further postponement easy. Dr. Durham's survey showed that the slightly consolidated, fine-grained gray Las Perdices shales outcrop along the coast west of Puerto Colombia for 7 to 8 kilometers, overlain unconformably by beds of unquestioned middle Miocene age (the *Turritella altilira* horizon). Not far away there is a thick section of lower Miocene deposits between these shales and the *Turritella* beds, which would seem to imply that not only is the correlation of the Las Perdices with the Aquitanian Stage the more plausible but that the age is more likely upper Oligocene than lower Miocene. At least this is the conclusion we draw from the data supplied by Dr. Durham. We are grateful to him for the detailed analysis he made of the stratigraphy of the area, even though the use of the information has been so long delayed.

The occurrence of a massive shell as the initial stock in a line is unusual in the history of most molluscan groups, for the trend normally is from rather unspecialized forms toward greater size or more elaboration. Here there is smoothness and solidity, and the direction taken by the *Talityphis* stock as it radiated northward, eastward, and northwestward during Miocene time was toward smaller, thinner shells, with a proportionately shorter spire and wider lip varix. The diamond shape of *T. precursor* persists in *T. pterinus* but is replaced by a more triangular outline in *T. lampada* KEEN, 1943 from the California Miocene and *T. alatus* SOWERBY, 1850 from the middle Miocene of the West Indies. In all of the species of *Talityphis,* the anterior canal and pillar area seems to be narrower and more tapering than in the closely related group, *T. (Typhisopsis)*.

The specific name is from the Latin noun ***praecursor,*** forerunner.

Siphonochelus (Siphonochelus) nipponensis
KEEN & CAMPBELL, spec. nov.

(Plate 10, figures 25 and 29)

Shell small, fusiform; color light tan; protoconch light brown, glassy, two convex whorls with a high keel on latest portion, nucleus central; teleoconch of 4½ whorls with an elevated spire; shoulder narrow, sloping, moderately channeled between whorls; varices four per whorl, of rounded oblique folds raised slightly above shoulder extending back to engulf preceding tubes; tubes markedly flattened in a spiral fashion, directed almost vertically and only slightly dorsally; tubes preceded by broad rounded intervarical folds that in turn are preceded by a sulcus containing apertural scars; varices strongly convex, contracting sharply at base; sculpture other than growth lines lacking; aperture oval, with produced lip; anterior canal long, narrow, closed, and bent to the right. **Type Material:** Holotype at present is in the Akibumi Teramachi collection, Kyoto, Japan. The paratype is in

Explanation of Plate 9

Figure 13: *Typhis (Talityphis) latipennis* DALL, 1919 (off Guaymas, Sonora, Mexico, 50 m; compare with *T. precursor*). Ventral view. × 1.3.

Figure 14: *Typhis (Talityphis) precursor* KEEN & CAMPBELL, spec. nov. Ventral view of holotype. UCDPTC no. 15083. × 1.27.

Figure 15: *Typhis (Typhisopsis) clarki* KEEN & CAMPBELL, spec. nov. Ventral view, holotype SUPTC 9724. × 2.25

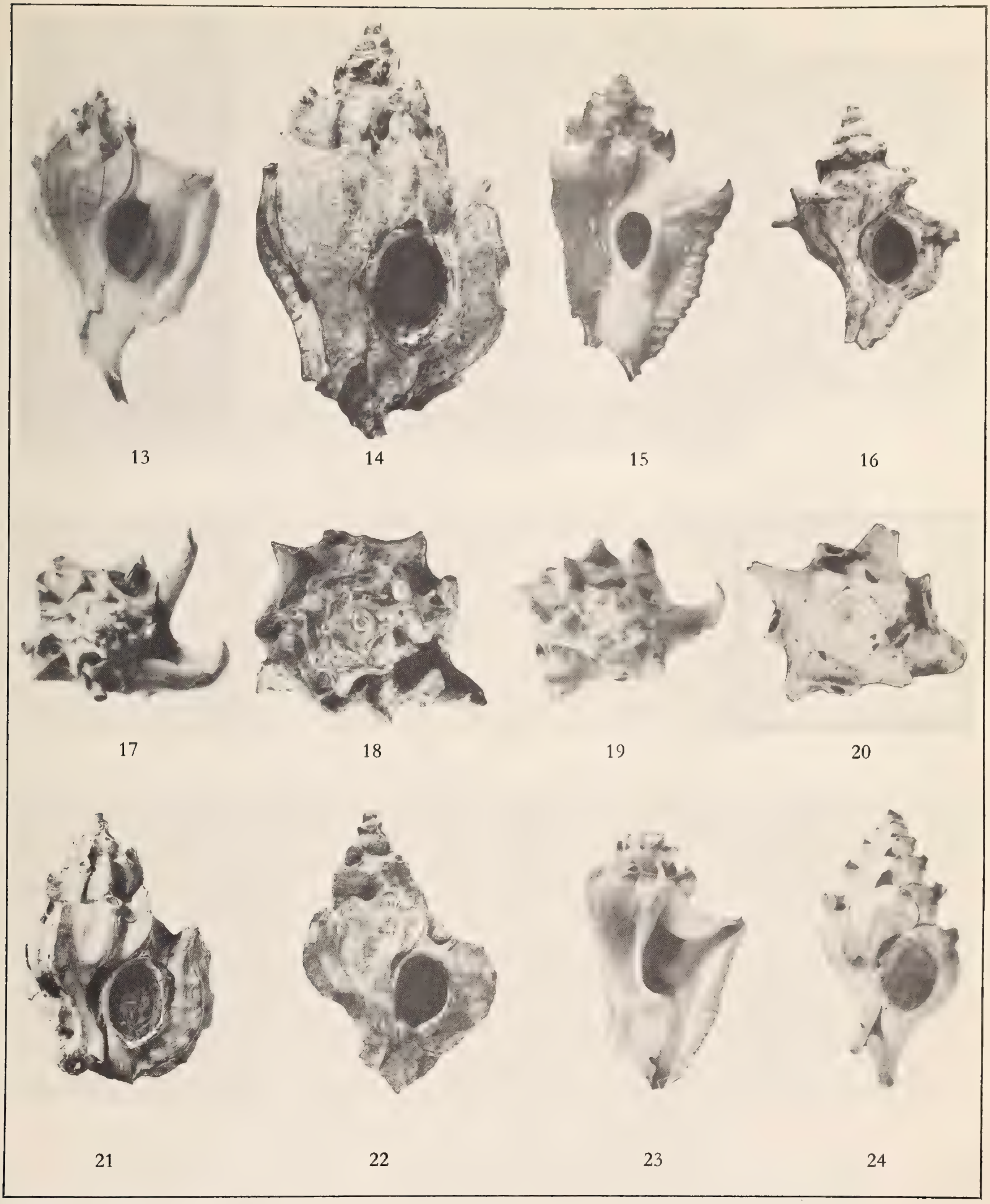
Figure 16: *Laevityphis (Laevityphis) schencki* KEEN & CAMPBELL, spec. nov. Ventral view, holotype. SUPTC no. 9723. × 1.9.

Figures 17 to 20: Apical views of the same shells as shown in top row. Same magnifications throughout.

Figures 21 and 22: Ventral views of hypotype and paratype IV, respectively, of *T. precursor.* × 0.8 and 1.0, resp.

Figure 23: Ventral view of paratype 9725 of *T. clarki,* showing the formation of the varical spine. × 2.1.

Figure 24: *Siphonochelus (Siphonochelus) arcuatus* (HINDS, 1843). (Off Cape Point, South Africa, 695-869 m; So. Afr. Mus. No. A4946) × 2.3.



13 14 15 16

17 18 19 20

21 22 23 24

photography: G. BRUCE CAMPBELL

the Stanford Univ. Paleo. Type coll. no. 9730. Exact replicas of the holotype have been prepared in natural color out of acrylic plastic. One is on deposit in the Stanford Univ. Paleo. Type Coll. no. 9731. As others are prepared they will be distributed among several major institutions.

Type Locality: Trawled off Tosa, Japan in excess of 200 m, both specimens. Lat. 33° 20′ N; Long. 133° 40′ E.

Age: Recent.

Dimensions: Height 10.8 mm, maximum diameter 5.1 mm (holotype).

Height 6.9 mm, maximum diameter 3.2 mm (paratype).

Remarks: This species most closely resembles the Italian Pliocene form *Siphonochelus fistulosus* (BROCCHI, 1814), (see Plate 10, figures 26 and 30), but in *S. nipponensis* spec. nov. the spirally flattened tubes are not nearly so wide and arched. The protoconch of the latter consists of 1¼ whorls of which the latest portion is definitely keeled. In contrast, *S. fistulosus* has a gradually expanding conical protoconch made up of four rounded whorls.

Siphonochelus nipponensis is the second member of the genus to be added to the Japanese fauna, the first being *S. japonicus* (A. ADAMS, 1863)[3].

It has only been recently (KEEN, 1944) that *Siphonochelus japonicus* has been recognized as a separate and distinct species from *S. arcuatus* (HINDS, 1843; see Plate 9, figure 24). The confusion was initiated by G. B. SOWERBY II (1874) when he listed *S. japonicus* as a synonym for *S. arcuatus* and added Japan to the Cape of Good Hope locality for the geographic range. Based on dredged material Dr. Habe established the authenticity of *S. japonicus* and Mr. Teramachi kindly gave us three specimens that had been trawled in 60 m off Sagami, Japan. The shell, glossy brown with spiral dark brown bands at the suture, periphery and base, has a flattened protoconch of one whorl or slightly less. Through the courtesy of Dr. K. H. Barnard we were able to examine and photograph three specimens of *S. arcuatus* trawled off South Africa. The varices are more sharply edged, the surface texture chalky and the protoconch has a globose nucleus with 1½ subsequent whorls.

We are indebted to Mr. Teramachi for supplying the only two known specimens of this new Japanese typhine.

Siphonochelus (Siphonochelus) erythrostigma

KEEN & CAMPBELL, spec. nov.

(Plate 10, figures 27, 31 and 35)

Shell small, fusiform, solid, color white with a small reddish brown dot at the base of each varix; anterior canal and prior canal remnants stained reddish brown; protoconch white, glassy, two convex whorls with a keeled paracentral nucleus followed by 4½ subsequent whorls; peripheral angle high; shoulder narrow, deeply channelled between whorls; varices four per whorl, each a rounded fold which extends above shoulder to join preceding varix and curves back to envelop preceding tube; tubes flattened, directed almost vertically and inclined only slightly dorsally, each with a suture on the anterior surface which is carried down on face of succeeding varix; varices strongly convex, contracted at base, with prominent spiral sculpture of six raised cords; intervarical area smooth, lacking secondary varical folds; aperture oval; anterior canal elongate, narrow, closed throughout; operculum of imbricated laminae, horn color, nucleus apical.

Type Material: Holotype is on deposit in the Stanford Univ. Paleo. Type Coll. no. 9732.

Type Locality: The holotype was collected in the Moreton Bay area off Brisbane, Queensland, Australia by Mr. Wicks, a prawn fisherman. Lat. 27° 20′ S; Long. 153° 15′ E.

Age: Recent.

Dimensions: Height 13.9 mm, maximum diameter 7.0 mm (holotype).

Discussion: The genus *Siphonochelus* is well represented in the Australasian typhine fauna, with three Recent species and two from the Tertiary, the oldest being *S. evaricosus* (TATE, 1888) from the Lower Miocene (Balcombian), Australia. The largest concentration of species is in the Tertiary of Europe, with the earliest species *S. parisiensis* (D'ORBIGNY, 1850) dating back to the Middle Eocene.

Recent intensive trawling and collecting around the Moreton Bay area of Queensland, Australia have produced a number of new species of mollusks among which was found the specimen of *Siphonochelus erythrostigma* spec. nov. Several differences set it apart from the other Recent species of *Siphonochelus*. The protoconch has a keeled eccentric nucleus and the whorls lack the intervarical folds or ridges seen so commonly in *Siphonochelus* and *Laevityphis*. The most remarkable feature is the six raised spiral cords that sculpture the varices only. This brings to mind a species from the Upper Eocene of Italy, *S. hortensis* (OPPENHEIM, 1900), which likewise has six raised spiral cords, but these cords are continuous across the varices and interspaces.

We are grateful to Mr. Oswald Rippingale for the referral of this unusual specimen of *Typhis*. We also acknowledge the courtesy of Mr. Anthony D'Attilio for forwarding the specimen to us and for lending pertinent *Typhis* material.

[3] This species possibly should be assigned to the subgenus *Lyrotyphis*, as it has five varices per whorl (see Plate 10, figures 28 and 32).

The specific name is from the Greek *erythros,* red, and *stigma* (a noun, neuter gender), spot or mark, referring to the distinctive red dots at the bases of the varices.

Laevityphis* (*Laevityphis*) *ludbrookae

KEEN & CAMPBELL, nom. nov. for *Typhis tripterus* TATE

(Plate 10, figures 33, 34 and 36)

1888 *Typhis tripterus* TATE. Roy. Soc. South Australia Trans. and Proc. and Report, **10:** 93, pl. 3, fig. 14 (not *Typhis tripterus* GRATELOUP, 1833).

1944 *Pterotyphis* (*Semityphis*) *"tripterus"* [TATE]. KEEN, A. M. Journ. Paleo., **18** (1): 61, 67.

1961 "?*Semityphis sp.* = *Typhis tripterus* TATE." VELLA, PAUL. Palaeontology, **4** (3): 380.

Shell of moderate size, biconic, elongate; spire markedly elevated; protoconch of $2\frac{1}{2}$ rapidly expanding, convex whorls followed by $3\frac{1}{4}$ subsequent whorls in holotype, five in hypotype I; varices averaging 3.6 per whorl in holotype, 3.4 per whorl in hypotype I, each a broadly rounded fold angled sharply at the shoulder and somewhat less at the base; tubes about midway between varices, directed radially, slightly dorsally, and only a few degrees apically; immediately anterior to tubes and within the intervarical space are secondary folds; just preceding these secondary folds are sulci with apertural scars; sutures rather deeply impressed; aperture oval; anterior canal wide, elongate, reinforced by remnants of previous canals, closed throughout, bent to right.

Type Material: Holotype and Paratype in the Tate Type collection at the University of Adelaide, Australia. Holotype on tablet labeled Adelaide University Geology Department No. T 453B; paratype on tablet A. U. G. D. No. T 453A. A topotype on loan from Dr. N. H. Ludbrook, Adelaide, has been studied; two hypotypes are in the Stanford Univ. Paleo Type Coll. no. 9733 and 9734.

Type Locality: According to Dr. M. F. Glaessner (*in litt.* 9 March, 1964), Tate failed to record exact localities and mounted specimens from different places together. Tate's locality was recorded as "Adelaide Bore, S. A. clayey green sand." The specimen on loan from Dr. Ludbrook perhaps pinpoints this locality more accurately. This shell was recovered from the "62 to 63 foot level" of Adelaide Childrens Hospital Bore 5. Lat. 34° 56′ S; Long. 139° 24′ E.

Other Localities: Hypotype I came from "Bed I. J. R. I.", Victoria, Australia, collected by F. Singleton. Dr. Glaessner (*ibid.*) commented that this locality is unidentifiable. The hypotype II, also collected by Singleton, came from Cape Otway, Victoria, Australia.

Table 2

Dimensions

	Height	Maximum diameter	Average number of varices per whorl[x]
Holotype A. U. G. D. No. T 453B	9.0 mm	5.0 mm	3.6
Paratype A. U. G. D. No. T 453A	12.0 mm	6.3 mm	4.2
Topotype (incomplete)	7.0 mm	4.2 mm	4.3
Hypotype SUPTC 9733	15.4 mm	11.1 mm	3.4
Hypotype II SUPTC 9734 (anterior canal broken)	11.0 mm	6.5 mm	4.3

[x] The total number of tubes or varices per shell is divided by the number of post-nuclear whorls.

Explanation of Plate 10

Figure 25: *Siphonochelus* (*Siphonochelus*) *nipponensis* KEEN & CAMPBELL, spec. nov. Ventral view of holotype. × 4.

Figure 26: *Siphonochelus* (*Siphonochelus*) *fistulosus* (BROCCHI, 1814). (Astian, Castel Arquato, Italy; Pliocene; *ex* Prof. Fr. Sacco). Ventral view. × 3.2.

Figure 27: *Siphonochelus* (*Siphonochelus*) *erythrostigma* KEEN & CAMPBELL, spec. nov. Ventral view of holotype, SUPTC no. 9732. × 3.4.

Figure 28: *Siphonochelus* (*Lyrotyphis*) *japonicus* (A. ADAMS, 1863). (Off Sagami, Japan; 60 m). Ventral view. × 5.

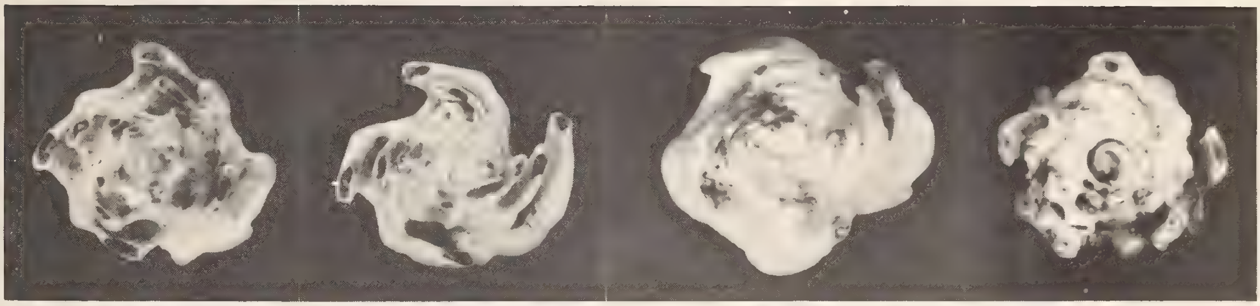
Figures 29 to 32: Apical views of the same shells as shown in top row. Same magnifications throughout.

Figure 33: *Laevityphis* (*Laevityphis*) *ludbrookae* KEEN & CAMPBELL, spec. nov. Ventral view of hypotype SUPTC no. 9733. × 3.0.

Figure 34: Apical view of shell shown in Figure 33. Figure 35: Lateral view of shell shown in Figure 27.

Figure 36: Dorsal view of shell shown in Figure 33.

25 26 27 28



29 30 31 32

33 34 35 36

photography: G. Bruce Campbell

Age: The Adelaide Bore and Cape Otway are both Upper Eocene.

Discussion: This species is significant systematically for several important reasons, among which is the fact that it represents the oldest Tertiary typhine from the Australasian area; furthermore it belongs to the genus *Laevityphis,* a group which had its origin in Europe and is represented by the earliest species yet described, *Laevityphis muticus* (Sowerby, 1834) from the London Clay of England (lower Eocene). Apparently during the Tethyan Sea period *Laevityphis* was dispersed widely from Europe, so that it has been found in the Southern United States, Central California, and Peru during the Middle and Upper Eocene and, in the opposite direction, in the Upper Eocene of Australia as *L. ludbrookae* nom. nov. In New Zealand the genus survived at least until the Upper Pliocene (Waitotaran) and is exemplified by *Laevityphis tepungai* (Fleming, 1943). Vella (1961) chose to create the new genus *Neotyphis* for Fleming's species on the basis of an incipient keel on the protoconch and nodules or vestigial spines on the crest of the varices below the spine at the shoulder. He pointed out that these features demonstrate the affinity of *Neotyphis* to *Typhis s. s.* Several species of *Laevityphis* and *Siphonochelus* display a keeled protoconch; as to the nodules or vestigial spines on the varices, *Laevityphis curvirostratus* (Conrad, 1847) from the Middle Oligocene of Mississippi has two nodules on the periphery of the varices, with corresponding sutures on the ventral varical faces. *Laevityphis gracilis* (Conrad, 1833) from the Alabama Eocene has in addition to the nodules and sutures three or four dorsally curving trough-shaped spines. The morphology of *L. tepungai* Fleming is certainly compatible with that of other members of the genus *Laevityphis.* It is not surprising to find vestigial features of *Typhis s. s.* displayed in *Laevityphis,* for probably *Laevityphis* either developed from an earlier species of *Typhis s. s.,* such as the undescribed Thanetian (Paleocene) species that Cossman (1903, p. 57) mentioned, or they both had a common yet undiscovered ancestor. It may be worthwhile retaining *Neotyphis* as a subgenus subordinate to *Laevityphis* to include those species that manifest vestigial features of *Typhis s. s.*

A puzzling feature shown by the holotype and hypotype SUPTC 9733 of *Laevityphis ludbrookae* is the unusual average number of varices per whorl, 3.6 and 3.4, respectively. This is perhaps what inspired Tate to name the species originally "*Typhis tripterus,*" indicating "three wings." In these two shells the neanic whorls approach four varices per whorl but as the shell grew larger the pace was not maintained; thus the average was less than four per whorl. The structure and appearance of the other three specimens, including the paratype, is the same as the holotype and hypotype SUPTC 9733 and the neanic whorls begin with the same pattern; in this case the 4.2 varices per whorl average is maintained.

Dr. Glaessner recently provided us with photographs of the type lots of Tate's species of *Typhis* and among the pictures was a 19 mm shell from the Eocene of Aldinga Bay, South Australia. It appears very similar to *Laevityphis ludbrookae* and has four varices per whorl. Tate apparently had intended this specimen to be the type of a new species which has only his manuscript name. This name -- which need not be mentioned -- means "four leaves." One might speculate that, after publishing "*Typhis tripterus,*" Tate decided to give a specimen with four varices per whorl a new specific name, which was never published. At the present time we consider that these specimens represent one variable species found in the Upper Eocene of Australia. It will take considerably more material to decide that the recognition of two distinct species is warranted.

The holotype and hypotype SUPTC 9733 of *Laevityphis ludbrookae* both show some signs of previous injury, which may account for the less than four varices per whorl average.

We take pleasure in dedicating to Dr. Nell H. Ludbrook of Adelaide, Australia this renamed species, in token of her contributions to Australian paleontology.

Laevityphis (Laevityphis) schencki Keen & Campbell,

spec. nov.

(Plate 9, figures 16 and 20)

Shell of moderate size, solid, biconic; protoconch partially missing and early spire whorls somewhat worn; shoulder sloping; periphery acute and contracted; body whorl markedly convex contracting sharply at base; varices four per whorl, narrow oblique folds crossing shoulder and joining previous whorl; top of each varix mounted by a long narrow radially directed spine located low on shoulder, bent anteriorly; tubes slightly closer to succeeding varix, joined to it by a buttress, angled slightly forward or ventrally, inclined moderately toward apex; aperture oval; anterior canal broad, reinforced by earlier canals, elongate, closed, inclined obliquely to the left.

Type Material: Holotype, Stanford Univ. Paleo. Type Coll. no. 9723.

Type Locality: Las Perdices Shale, Puerto Colombia, Dept. Atlántico, Colombia, collected by Dr. Hubert G. Schenck, ca. 1933. Lat. 11° 03′ N; Long. 75° 00′ W.

Age: Upper Oligocene (possibly Lower Miocene), correlative with the Aquitanian Stage of Europe.

Dimensions: Height 19.0 mm, maximum diameter 15.2 mm (holotype).

Remarks: *Laevityphis (Laevityphis) schencki* spec. nov. has the closest affinity to *L. (L.) sawkinsi* (MANSFIELD, 1925) from the Lower-Middle Miocene of Trinidad. It differs from the Trinidad species by having a sloping shoulder and the radial, anteriorly inclined varical spines located lower on the periphery than the tubes. It perhaps represents the Oligocene precursor to the Miocene *L. sawkinsi* (MANSFIELD).

The holotype has been in the Schenck collection at Stanford University labelled as *Typhis siphonifera* DALL, 1915, but it shows a number of points of difference from that species. The intervarical spines do not point toward the apex as they do in *T. siphonifera,* and the shoulders of the whorls are wider and more sloping; also, the spire is lower. The same differences may be noted for distinguishing the new species from *T. costaricensis* OLSSON, 1922, figured by ANDERSON from Colombia in 1929 as *T. siphonifera* (Proc. Calif. Acad. Sci., ser. 4, vol. 17, p. 138, pl. 9, fig. 8). The holotype and only known specimen of *Laevityphis schencki* came, apparently, from the same beds as the half-dozen specimens of the *Talityphis* that is herein described as new. Recently *Typhis costaricensis* has been figured from Colombia (BARRIOS M., 1960), but apparently from a higher horizon. From the available evidence it would seem that both *T. siphonifera* and *T. costaricensis* are from beds slightly younger than the Las Perdices shale. Both are, like *T. sawkinsi* MANSFIELD, good candidates for reassignment to the genus *Laevityphis,* subgenus *Laevityphis, s. s.*

It is significant that the tubes in *Laevityphis schencki* are inclined forward or ventrally, and although they are not welded to the succeeding varix, this trend does suggest that one of the earlier species of *Laevityphis* provided the ancestral stock for the East Indian group, *Indotyphis* KEEN, 1944.

We take pleasure in naming this species for the late Dr. Hubert G. Schenck, who collected the holotype and who provided much encouragement and guidance in the original review of Typhinae and on the stratigraphic problems posed by the Las Perdices shale.

Pterotyphis (Tripterotyphis) fayae KEEN & CAMPBELL, spec. nov.

(Plate 11, figures 39, 40, 43 and 44; Text figures 1 and 2)

Small, ivory-white, irregularly blotched with brown, especially at periphery of whorls, the color stronger in interspaces of spiral ribs, giving the appearance of fine color-banding; whorls 7 to 8, varices 3 per whorl, the upper end of each varix left open as a tube; outer face of varix with about 22 spiral ribs; sculpture of shell of numerous raised spiral ribs, their interspaces rendered scaly by axial lamellae; aperture oval, outer lip with a sinuous margin, reflected against the ends of 10 spiral ribs, smooth within or with a few low lirae; anterior canal sealed except at end; pillar with remnants of 3 previous canals.

Type Material: Santa Barbara Museum of Natural History, no. 15999 (holotype); paratypes, Santa Barbara Museum of Natural History; Stanford University Paleo. Type Coll. no. 9726; other paratypes to be distributed.

Type Locality: Barra de Navidad, Jalisco, Mexico. Collected by Faye Howard and Gale Sphon (Churea Expedition), January 7 to 11, 1962. 100 specimens. Lat. 19° 17′ N; Long. 104° 48′ W.

Other Localities: Tenacatita, Jalisco, Mexico (Churea Expedition), February 5 to 8, 1963 (17 specimens);

Explanation of Plate 11

Figure 37: *Pterynotus (Nothotyphis) norfolkensis* FLEMING, 1962. Ventral view of paratype GSNZ no. TM 3146. × 5.5.

Figure 38: *Pterotyphis (Pterotyphis) fimbriatus* (A. ADAMS, 1854). (Tenacatita, Jalisco, Mexico). Ventral view. × 2.25.

Figure 39: *Pterotyphis (Tripterotyphis) fayae* KEEN & CAMPBELL, spec. nov. (Cape San Lucas, Mexico). Ventral view of hypotype. × 2.75.

Figure 40: Paratype SUPTC no. 9726 of *P. fayae* (apertural rim broken). Ventral view. × 1.7.

Figure 41: Dorsal view of shell shown in Figure 37.

Figure 42: Apico-lateral view of shell shown in Figure 38 (note displacement of tube, increasing with growth).

Figure 43: Lateral view of hypotype of *P. fayae* (Pleistocene, Oaxaca, Mexico). Approximately × 3.0.

Figure 44: Dorsal view of holotype of *P. fayae,* SBMNH no. 15999. × 1.7.

Figure 45: *Distichotyphis vemae* KEEN & CAMPBELL, gen. nov. et spec. nov. Ventral view of holotype, AMNH no. 110459. (Off Panama-Costa Rica coast, 1892 m). × 5.5.

Figures 46 and 47: Lateral and dorsal views respectively of the same shell as shown in Figure 45.

photography: G. BRUCE CAMPBELL

Bahía de Audencia, Colima, Mexico (Churea Expedition), January 1 to 2, 1962, 1 specimen; Rancho El Tule, near Cape San Lucas, Mexico, collected by Faye Howard, February 1964 (41 specimens); Pleistocene, Oaxaca, Mexico, collected by Robert Palmer, ca. 1925; 1 specimen, at Stanford University.

Age: Recent; also Pleistocene.

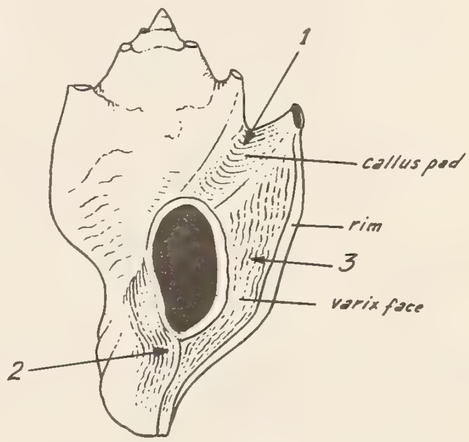
Dimensions: Holotype, height, 19.9 mm, maximum diameter, 11 mm, length of aperture, 4.6 mm. Paratype I, height 20.5 mm, diameter, 11.5 mm; paratype II, height, 22 mm, diameter, 12 mm.

Remarks: It is an unusual circumstance to be able to describe a new species with more than 150 specimens available, and one wonders that the form has for so long been overlooked. The habitat is evidently somewhat off-shore, because all specimens seen (except possibly one juvenile) were crab shells.

There are two American species of *Tripterotyphis* with which this may be compared. From *Pterotyphis* (*Tripterotyphis*) *lowei* (Pilsbry, 1932) of the West Central American coast, this is easily separable on the basis of the fine sculpture and the narrower outline. It is no closer to the Caribbean species long known as *Typhis cancellatus* (Sowerby, 1841), and the latter is larger (length about 27 mm), with tubes that are turned outward at the ends. As Sowerby's specific name is a primary homonym, a replacement will be required unless study of the type of *Typhis triangularis* Adams, 1855 confirms it as a candidate.

A New Zealand species recently made the type of a new subgenus bears a strong morphological resemblance to all three of the American species. This has been called *Pterynotus* (*Nothotyphis*) *norfolkensis* Fleming, 1962 (Plate 11, figures 37 and 41), the varical tube being interpreted as closure of a guttered spine. Another similar form occurs in the Oligocene-Miocene of Europe, *Typhis tripterus* Grateloup, 1833. [Parenthetically it may be remarked that under the new International Code of Zoological Nomenclature, this is not a homonym of *Murex tripterus* Born, 1778 and need not be replaced by the later name *Typhis wenzelidesi* (Hörnes, 1856)].

Whether or not *Nothotyphis* is to be considered a synonym of *Tripterotyphis* apparently must be determined by a study of the manner of formation of the varices. In *Tripterotyphis* this can now be worked out in



Text figure 2: Diagrammatic sketch of varix formation in those Typhinae that have a wide lip; numbered arrows indicate the areas of growth and the order in which they are consolidated.

detail, thanks to a growth series among the abundant specimens at hand. Varix formation takes place in the same way it does in other of the typhine groups with a wide lip varix, such as *Pterotyphis, Talityphis,* and *Typhisopsis*. The sequence is as follows: The varix develops first as a flat sheet, its outer edge strengthened by a narrow rim that remains differently sculptured from the rest of the completed structure and is marked off by an incised line like a suture; at the intersection of this flat sheet with the body whorl at its posterior end there is at first a notch, which in *Pterotyphis* becomes the site of the tube (see text figure 1). Closure begins in three areas -- from the upper part of the varix sheet downward toward the aperture, as shown in the diagram, text figure 2, forming the callus pad; second, and perhaps simultaneously, from the columellar margin of the canal outward, and, lastly, from the outer rim

Text figure 1: Immature specimen of
Pterotyphis* (*Tripterotyphis*) *fayae
showing the first phase of varix growth, the outer rim of the varix not yet formed.

inward, usually in a series of festoons. In *Tripterotyphis* the varix face in the third stage develops a sort of platform, the apertural cavity back of it being triangular and only gradually filling in from the outer margin so that the apertural wall becomes even with the lip edge. The tube that is the hallmark of the Typhinae develops during the process of closure and becomes a part of the varix, whereas in the *Typhinellus - Talityphis - Typhisopsis* line the tube does not form until after the varix is completed, and then it may lie either against the pad (as in *Typhisopsis*) or be slightly removed from it. In *Pterotyphis,* as shown above, the tube develops in advance of the varix. *Tripterotyphis* seems, therefore, to be morphologically closely related to other Typhinae rather than to the muricine group *Pterynotus* SWAINSON, 1833.

Along with the new species of *Tripterotyphis,* two other similar species of Typhinae came to light, both constituting new records. At the type locality -- Barra de Navidad, Jalisco -- two specimens of the long-lost *Pterotyphis fimbriatus* (A. ADAMS, 1854) (see Plate 11, figures 38 and 42) were taken. This species had been made the type of a subgenus — *Trigonotyphis* JOUSSEAUME, 1882. The specimens confirm what the illustration seemed to us to show, that this group is in no way distinguishable from *Pterotyphis, s. s.*; thus, it falls as a synonym. Also, the specimens prove conclusively that the species was correctly attributed to the Panamic marine fauna. Among the specimens of *P.* (*Tripterotyphis*) *fayae* from Cape San Lucas there were 4 of *P.* (*T.*) *lowei* (PILSBRY), a slight extension of the known range of that species. These specimens, a growth series, demonstrated the distinctness of the two forms at every stage.

We are pleased to dedicate this unusual new find to an industrious collector who has added much in recent years to our knowledge of Panamic province mollusks — Faye Howard.

Among the deep-water material dredged by Lamont Geological Laboratory's oceanographic vessel, the Vema, off the west coast of South and Central America was a single specimen of a bizarre mollusk that seems to be a member of Typhinae. A new genus is necessary, however, for its reception.

Distichotyphis KEEN & CAMPBELL, gen. nov.

Type species, *D. vemae* KEEN & CAMPBELL, spec. nov.

Varices two per whorl, tubes broad at base and evenly tapering, diverging at nearly a right angle from axis of shell or pointing slightly anteriorly; anterior canal long, closed, recurved.

Distichotyphis vemae KEEN & CAMPBELL, spec. nov.

(Plate 11, figures 45 to 47; Text figure 3)

Shell small, white, almost transparent, with several whorls (only 4 in holotype, the apex being broken off and sealed from within, showing an oval scar over what would have been a tube); varices in two parallel ranks, formed of the conical tubes and marked by the remnants of the outer lips of former apertures; apertural face of each tube showing a fine suture line medially, corresponding to a low ridge on the back of the tube, which forms the periphery of the whorl; anterior canal tubular, closed except at its end, arched backward in a broad curve; aperture oval, relatively large, bordered by a continuous, slightly thickened and free-standing margin; pillar imperforate but showing traces of two earlier positions of the anterior canal; operculum not visible in aperture.

Type Material: Holotype - American Museum of Natural History, Department of living Invertebrates, catalogue no. 110459.

Type locality: Vema station V-15-60, Lat. 06° 21′ N, Long. 85° 17′ W, off the Panama-Costa Rica coast, in 1016 fathoms (uncorrected) = 1892 meters depth; Nov. 30, 1958.

Age: Recent.

Dimensions: Height (apical whorls missing), 8 mm; diameter, 8 mm; height of aperture, 1.75 mm.

Remarks: So striking is the resemblance of this form to a Jurassic genus, *Spinigera* ORBIGNY, 1850 (see text figure 3), that we had visions of another long-extinct group being brought to light, in parallel fashion to *Neopilina,* which first was taken in the same general region. However, closer study ruled out this pleasant prospect. Photographs of fossil specimens of *Spinigera* show that the extensions

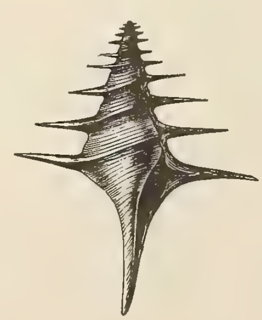


Fig. 723. S. longispina.

Text figure 3: *Spinigera longispina* DESHAYES, 1850 (After CHENU, 1859); Jurassic, France. × 1.

are spines, not tubes; that the aperture is not set off by a raised margin; the anterior canal is straight, not recurved, is open for its entire length; finally, that the shells are much larger (to 40 mm in length). Similarity of form may be seen not only in the double ranks of extensions but also in the spiral ridge at the periphery of each whorl.

The unique holotype was apparently taken alive, as the soft parts may be seen in the central cavity of the second and third whorls and in part of the last. The operculum, if present, is retracted beyond visibility. The shell is too small and delicate to risk probing for it. The final tube is open, the others apparently walled off at their junction with the central cavity, for the tubes show up as white, the axial portion of the shell as waxy yellow because of the søft parts within.

The generic name is from the Greek *dis,* two, and *stichos,* row, combined with *typhis,* which originally signified smoke but by extension was evidently intended to imply chimney (referring to the open tubes) by MONTFORT, the author who first proposed a generic name in Typhinae.

Our thanks go to the American Museum of Natural History, Department of Living Invertebrates, for the privilege of describing the deepest-water member of the Typhinae yet to be recorded.

ACKNOWLEDGMENTS

In addition to the persons already mentioned in the descriptions, we are indebted to a number of collectors and museum curators for their aid in the loan of material for our study. These include especially Dr. K. H. Barnard of the South African Museum; Mr. and Mrs. John Q. Burch, Los Angeles; Mr. and Mrs. Crawford N. Cate, Los Angeles; Mr. Thomas Darragh, University of Melbourne, Australia; Dr. C. A. Fleming, New Zealand Geological Survey; Mr. George Kanakoff, Los Angeles County Museum; Dr. Donald F. McMichael, Australian Museum, Sydney; Dr. Hope MacPherson, National Museum of Victoria, Melbourne; Dr. Katherine v. W. Palmer, Paleontological Research Institution, Ithaca, N. Y.; and Dr. Donald R. Shasky, Redlands, California. To all of these and to all the others who have helped in the preparation of this report, our thanks.

LITERATURE CITED

BARRIOS M., MARGOTH

1960. Algunos moluscos del Terciario medio de Colombia. Boletin Geologica, Servicio Geol. Nacional, Bogota, **6** (1 - 3) : 213 - 306; 12 plts.

COSSMANN, MAURICE

1903. Essais de paléoconchologie comparée. Paris: 13 livr. 1895 - 1925. (Typhinae, livr. **5**: 56 - 63; plts. 2 - 3)

FLEMING, C. A.

1962. The genus *Pterynotus* SWAINSON (Gastropoda, Family Muricidae) in New Zealand and Norfolk Island. Trans. Roy. Soc. New Zealand, Zool. **2** (14) : 109 - 119; 22 figs.

KEEN, A. MYRA

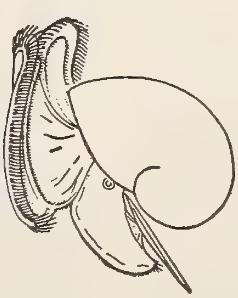
1944. Catalogue and revision of the gastropod subfamily Typhinae. Journ. Paleontology **18** (1) : 50 - 72; 20 figs.

SOWERBY, GEORGE BRETTINGHAM (second of name)

1874. Description of twelve new species of shells. Proc. Zool. Soc. London for **1873**: 718 - 722; plt. 59. (April 1874)

VELLA, PAUL

1961. Australasian Typhinae (Gastropoda) with notes on the subfamily. Palaeontology, **4** (3) : 362 - 391; plts. 46 - 47.



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BOOKS, PERIODICALS, PAMPHLETS

Late Cenozoic Pelecypods from Northern Venezuela

by NORMAN E. WEISBORD. Bulletins of American Paleontology (Paleontological Research Institution, Ithaca, New York, Volume XLV, Number 204, pp. 1 to 564, plts. 1 to 59, 8 text figs.; 18 February, 1964.

This volume (a companion to the one dealing with the gastropods in the same faunal assemblage) deals with 172 species of pelecypods of which 29 are Recent, 22 both Recent and fossil, and 121 known only as fossils. One Recent species and 63 fossil forms are described as new. The fossils were collected from strata assigned Pliocene and Pleistocene ages.

Each species is described, illustrated and accompanied by extensive synonymy. In addition, comparative notes, bibliography and index, all combine to make this volume indispensable for anyone interested in late Cenozoic pelecypods of northern Venezuela or adjacent regions, including the eastern Pacific.

LGH

Fossils in America

by JAY ELLIS RAWSON. Harper and Row: New York. Pp. xii + 402, 27 text figs, 8 plts. $ 8.95.

The subtitle states the purpose — to indicate the nature, origin, identification and classification of fossils, and to give a range guide to collecting sites. The work is divided into three parts. The first consists of six chapters on general information useful to the would-be collector of fossils. Sample illustrations are given for both plants and animals that occur in the fossil record. Part two is a list, culled from the literature, of recorded collecting localities in each of the 50 United States; these are arranged alphabetically by county. In Part Three there is a glossary

and a list of libraries and museums, as well as an annotated bibliography.

MK

Proceedings of the Malacological Society of London

vol. 36, part 1, April 1964.

P. Dinamani: Feeding in *Dentalium conspicuum*.

K. H. Barnard: Two new genera of Erynacea (Bivalvia) from South Africa.

MK

Venus: Japanese Journal of Malacology

vol. 22, no. 4, March, 1964

Tokubei Kuroda: On an *Apicalia* (Gymnoglossate Gastropoda) from the China Sea.

Katura Oyama: On the confused usage of the genus *Ranella* and the allies.

Takashi Okutani: Thecosomatous Pteropoda collected during the second cruise of the Japanese Expedition of Deep Sea.

Iwao Taki: On the chiton fauna of Japan (1). The status of *Ischnochiton comptus* and *I. boninensis*.

Masao Azuma: Notes on the radula of *Perotrochus africanus* (Tomlin, 1918).

Kohman Y. Arakawa: A study on the radulae of Japanese Muricidae (2).

Masao Nakazima: On the differentiation of the crenated folds in the mid-gut-gland of Eulamellibranchia (IV).

Iwao Taki: Classification of the Class Polyplacophora, with a list of Japanese chitons.

[N. B.: Only the titles for which there are abstracts in English are cited above.]

MK

Paleontological Implications of Shell Mineralogy in Two Pelecypod Species

by James R. Dott. Journ. Geology, vol. 71, pp. 1 to 11, figs. 1 to 8; January, 1963.

The shell mineralogy (calcite and aragonite) of *Mytilus* species living along the Pacific Coast of the United States is variously related to temperatures and salinities of the water in which the animals live. Specimens of *M. californianus,* longer than 15 mm, exhibit aragonite percentages which increase with both water temperatures and with shell thickness. The species lives only within a narrow range of water salinities. The shell mineralogy of *M. edulis edulis* and *M. edulis diegensis* does not change so significantly through the range of water salinities and temperatures sampled. *Mytilus edulis* from Woods Hole, Massachusetts, varies more widely in shell mineralogy than do West Coast examples, possibly reflecting the wider temperature range to which the former are subjected.

ECA

Selected Shells of the World Illustrated in Colour - (I)

by Tokio Shikama, Geological Institute, Yokohama National University, and Masuoki Horikoshi, Ocean Research Institute, Tokyo University. 126 pp., 102 color plates, 211 text figures; 10 December, 1963. M. Fukuda, publ., Tokyo. Price $ 25.-, incl. postage.

Perhaps the finest we have seen to date among the many superb examples of color reproduction produced in Japan, this work presents an excellent cross-section of rare and common marine gastropod species from all parts of the world — the first of several recent Japanese shell books to deal with species not exclusively Japanese.

Among the more popular family-groups of gastropods covered in this book are colored illustrations of approximately 100 species each of cowries, cones, muricids and volutes, respectively; there are about 60 species of Mitridae and about 20 of Terebridae, along with numerous other groups.

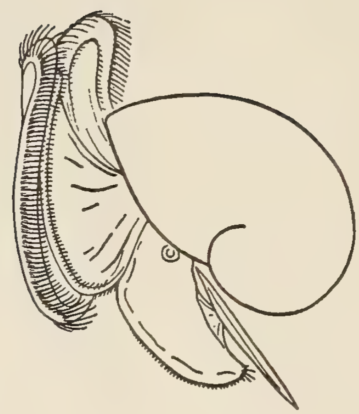
While the text is entirely in Japanese, the book is nevertheless a useful tool for conchologists everywhere, as it provides a comprehensive index in English as well as furnishes complete scientific shell names and their authors in text and in plate explanations. There are numerous fine black and white photographic text figures in addition to the 102 color plates, with the respective magnifications indicated in all instances.

The species seem to be accurately identified, and typical localities (but not ranges) are given. The taxonomic arrangement is up to date, and there is a systematic outline of gastropod family-groups, in English, which could well be used as a guide in arranging any heterogeneous collection of gastropods. The few misspellings that occur seem of relatively little importance when considered alongside the truly spectacular color photographs.

This is a book to delight the non-collector as well as the serious conchologist. It is hoped that an English translation of the text will be included in future editions.

Publication of Part II of this work, covering Opisthobranchia, Pulmonata, Scaphopoda, Pelecypoda, Cephalopoda and Amphineura, is expected in early 1964.

JMC



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(signed) R. Stohler, Editor.

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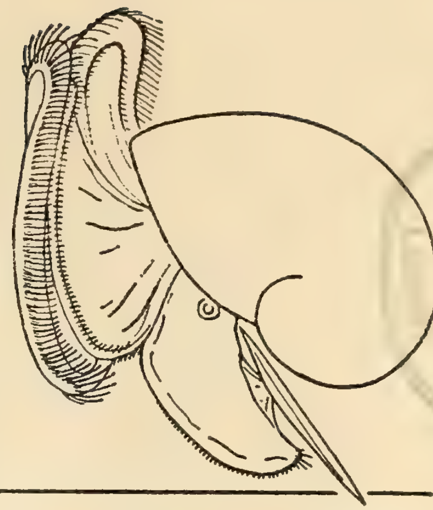
Manuscripts should be typed in final form on a high grade white paper, 8½" by 11", double spaced and accompanied by a carbon copy.

THE VELIGER



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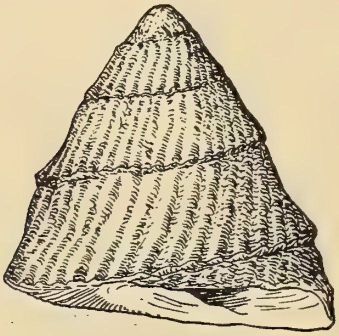


Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION, Subdivision,** SECTION,
SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).
New Taxa

The Conidae of Fiji

(Mollusca: Gastropoda)

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands

(Plates 12 to 18; 3 Text figures; 1 Map)

THIS FAUNAL STUDY comprises the existing knowledge of the genus *Conus* from Fiji waters. The majority of specimens have been reef-collected, while others were obtained through dredging to a depth of 16 fathoms; subsequent dredging in deeper water may very well bring to light additional species. Only shells collected by the author and collectors residing in Fiji were used in the compilation of statistical data and specific records.

The majority of *Conus* species recorded from Fiji have an Indo-West Pacific distribution; three species reach as far as the West Coast of America.

Notes on the geography of the Fiji Islands and other pertinent data have been given in a previous publication (CERNOHORSKY, 1964).

HABITAT AND VARIATION

During the daytime animals of *Conus* remain buried in sand or hidden under coral boulders and crevices of the coral reef. They are mainly nocturnal, and certain species, such as *Conus eburneus* HWASS in BRUGUIÈRE may be found at night exposed on reef-flats and among weed, in large colonies. The various *Conus* species have their preferred habitat, living either in stretches of sand, or are completely or partially buried in sandy substrate under coral boulders, or even inhabit crevices of coral reefs. It has been noticed that juvenile animals prefer the slightly deeper off-shore waters to the intertidal reef area where most of the adult specimens are found.

The colour and arrangement of design on the body whorl of *Conus* is one of the most variable features; certain species, such as *Conus magus* LINNAEUS and *C. lachrymosus* REEVE are more variable in this respect than others. The height of the spire is another variable feature; the spire itself will range from concave to convex in certain specimens. In large series of populations aberrant shells appear less obvious as there are many intermediate specimens connecting the normal form with the extreme variant. Only through study of large series of shells of a given species can one appreciate the actual range of variation within that species.

Juvenile shells, when only one sixth of their ultimate adult size, already display a nearly completed colour pattern; they will, however, have the waxen appearance and strong spiral ridges and granules characteristic of juveniles. The thin lip in *Conus* cannot be interpreted as a sign of immaturity, as thin-lipped specimens may be sexually mature and have been observed in the act of oviposition.

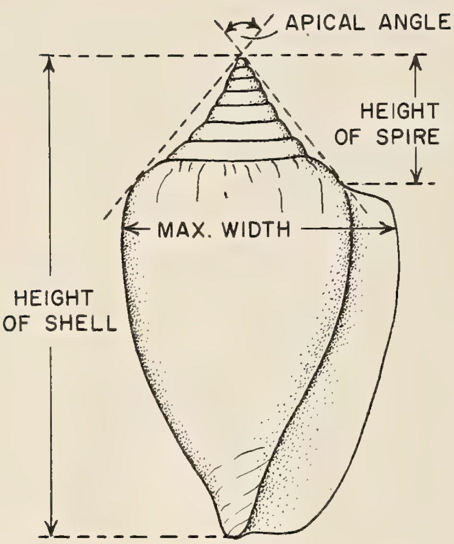
THE ANIMAL

Part of the foot is responsible for the deposition of colour and pattern on to the shell, while the sole of the foot is used for locomotion. The siphon takes in water and keeps the animal supplied with oxygen; the tentacles are tactile feelers and on them are situated the eyes. The proboscis assists in feeding and is responsible for the delivery of the radula tooth to the victim.

The radula of *Conus* consists of two teeth per row; the teeth taper anteriorly and are barbed at the end. Posteriorly they are attached by a ligament to the radula. The tooth is either hollow or grooved along the surface, forming a narrow canal. One tooth is detached from the somewhat L-shaped radula sac, enters the pharynx and is securely gripped by the proboscis. At the moment of attack, poison is secreted from the venom bulb and passes through a tubular duct into the esophagus and to the tooth, which is then thrust into the victim. The tooth remains firmly anchored in the victim's flesh, and the action is repeated, if necessary. *Conus* feed in nature on annelids and on other gastropod mollusks and have been observed to kill and consume one of their own kind.

KOHN, SAUNDERS & WIENER (1960) reported the crude venom of *Conus* to be yellow, viscous and granular in appearance, with protein and carbohydrate present. The composition of *Conus* venom is very complex; it is, however, highly neurotoxic and death is due to respiratory failure, preceded by heavy salivation, chest constriction and convulsions.

The study of ENDEAN on venomous cones (1962, p. 5) revealed that piscivorous members of the genus *Conus*,



Text figure 1: View of *Conus* shell, showing measurement recorded.

such as *C. geographus, C. tulipa, C. striatus* and *C. catus,* possess venom which is toxic to all vertebrates, while the venom of molluscivorous species has no effect on vertebrates. Some vermivorous species possess venom capable of inflicting some local tissue damage in vertebrates.

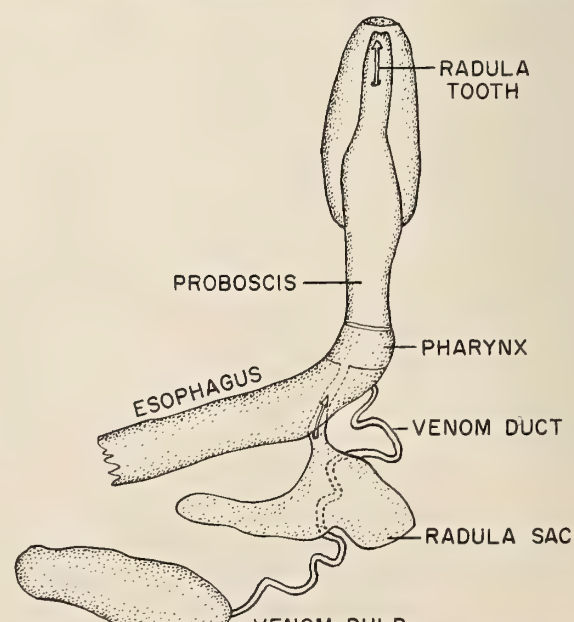
Conus bites can prove fatal to human beings; Kohn (1963) recorded 37 *Conus* stings, 10 of which were fatal. During 1963 two more fatalities were reported by Australian newspapers as having occurred in New Guinea and New Caledonia. Collectors are advised to handle *Conus* at the shoulder, which is well away from the proboscis. Should, however, a bite be inflicted it should be treated the same way as a snake bite.

The few egg cases of *Conus* observed in Fiji were usually laid in a cluster or in parallel rows and firmly anchored to the substrate; the height of egg capsules varied from 6 mm to 26 mm; capsules were of a generally oval shape, coloured, and with either a smooth or a ridged surface. In one instance, 14 *Conus leopardus* were observed congregated in a circle around some egg clusters, with their bases pointing toward the centre of the circle. It is assumed that egg laying is a family affair, as it seems highly improbable that all 14 individuals were females.

CLASSIFICATION

The identification of the shells conforms to the present day knowledge and interpretation of the various species of *Conus.* The nomenclature of the genus, however, is at present in a transitional stage of confusion due, no doubt, to the excess of synonyms, homonyms, colour forms and plain ecological variants. A great number of type specimens have become lost or destroyed, while those that are extant are not easily accessible. Many original descriptions are too short and ambiguous for positive identification and often lack accompanying figures; those which are illustrated show figures which are of a dream-like quality, and are often exaggerated. Certain species, such as *C. achatinus* Gmelin and *C. monachus* Linnaeus, have through the ages been interpreted by different writers in various ways. To add to the confusion, many early writers named a specimen, not a species; the lack of reference material was largely responsible for it. Workers may therefore be tempted to re-describe as new all dubious species, either to bring order into nomenclature or just to escape uncertainty of correct interpretation. It is to be preferred, however, to try to match nameless species to the most appropriate descriptions and illustrations already in existence, instead of creating possible further synonyms. In a number of instances this may not be an easy matter, and results will vary according to the personal concept of, or interpretation of type-figures and descriptions by the various workers concerned. Unless the whole group of *Conus* is thoroughly revised by tracing every single species back to its original author, his description, illustration and type-specimen, and unless pertinent synonymy is compiled, the correct interpretation of certain species of *Conus* will remain open to dispute.

Various attempts have been made to split the genus *Conus* into further genera and subgenera. Montfort

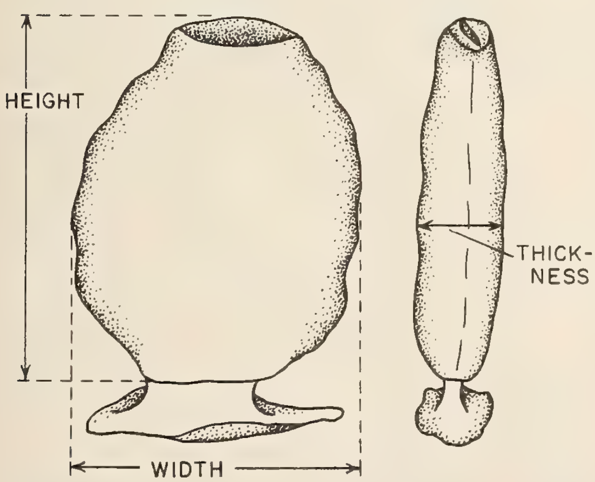


Text figure 2: Generalized view of the venom apparatus and part of the anatomy of *Conus.*

(1810), Swainson (1840), and Mörch (1853), all established new genera, and Iredale (1930), and Cotton (1945) added others. Cotton (*l. c.*) distinguished no less than 14 groups comprising 30 genera, and in a recent paper (Cotton, 1958) split the genus *Conus* into 3 subfamilies and 25 genera. Morrison (*fide* Dodge, 1953) arranged Linnaeus' 32 species of *Conus* in one genus, 13 subgenera and 8 sections on the basis of sculptural differences.

The dividing of *Conus* into genera and subgenera has usually been based on single characters such as sculpture, colour, height of spire and general shape of shell; these characters are, however, more appropriately used in distinguishing species, not genera. Dr. Kohn (*in litteris*), when referring to the use of single characters, points out that in a "generic" arrangement based on sculptural characters the arrangement of species differs markedly from one based on the use, for example, of radula characters.

Confusion exists even among the subdividers of *Conus* in regard to the correct "generic" interpretation of the various morphological characters. The well-known species, *Conus striatus* Linnaeus, has been placed in the genera *Conus, Cucullus, Leptoconus, Tuliparia, Chelyconus, Phasmoconus, Dendroconus* and *Pionoconus* by various writers. It is obvious that single shell characters are poor criteria indeed for generic arrangement, if they can be interpreted by a few authors in so many ways. A generic division of *Conus* will always appear artificial if based on morphological characters alone; due consideration should be given in such an arrangement to fossil records, radular characters and the living animal. Clench (1942), Kohn



Text figure 3: Generalized view of egg capsule of *Conus* (approximately x 4.0)

(1959) and Hanna (1963) do not support a further subdivision of *Conus* for similar reasons.

Dr. A. Kohn was kind enough to communicate to me his opinion on the value of radula teeth for use in comparative studies of species. He is of the opinion that certain groups of *Conus* species with similar shells (*e. g. textile* group) have also similar radular teeth; in such a case the latter are of little value in solving taxonomic problems. Certain other species groups with similar shells can be readily separated on the basis of radular teeth: *Conus lividus* from *C. flavidus, C. flavidus* from *C. frigidus, C. betulinus* from *C. suratensis,* and *C. ochroleucus* from *C. radiatus.*

METHODS and OBSERVATIONS

Large series of most *Conus* species were available for statistical measurements with the exception of very rare species; in the latter case the range listed does not represent a true indication of the actual limits of variation.

To show the range of variation within a species the minima and maxima of height and width, height of spire and apical angle have been recorded. The abbreviations used have the following meanings:

H =Height of shell from apex to base in millimeters
W =maximum width of shell expressed in per cent of height
HS =height of spire from the junction of the aperture to the apex
AA =apical angle, formed between the shoulder, apex and the opposite shoulder

The approximate average height of a species is: minimum height plus maximum height divided by 2.

ACKNOWLEDGMENTS

I wish to express my appreciation and gratitude to Dr. A. Kohn for the helpful suggestions and information he supplied to me. I am indebted to Dr. Wright Barker for his patient compilation of reference material and photographs of type-figures of various *Conus* species, and to Dr. D. McMichael from the Australian Museum for pertinent references. My thanks are due to Dr. R. Stohler for his encouragement and tireless assistance, and Mr. A. Jennings for information supplied on the ecology and animals of various species and the loan of study material. I would like to thank Messrs. I. Morse, J. Farkas, G. Broesel and Mr. and Mrs. W. J. Erich for the loan of their Fijian study material, and the British Museum (Natural History) for permission to reproduce the colour photograph of Reeve's holotype of *Conus emaciatus,* which was taken and kindly made available by Dr. Kohn.

VANUA LEVU
Yasawa
Nacula
YASAWA GROUP
Naviti
Waya
Waya Lailai
Vorno
MAMANUCA GROUP
Mana
Malolo
Lautoka
NADI
Momi
Natadola
CUVU
Sigatoka
Korotogo
Sovi Bay
Korolevu
Hadrega reef
Deuba
Yanuca
VATIA
TAVUA
Ellington Wharf
RAKIRAKI
Viti Levu Bay
VITI LEVU
Lodoni
TAILEVU
Bau
Kaba Pt
SUVA
Navua
Nukulau
Nasilai
Makogai
Levuka
Wakaya
OVALAU
BEQA
VATULELE
KADAVU PASSAGE
Dravuni
Bulia
Ono
KADAVU
Vunisea
17°
18°
19°
20°
NEW GUINEA
NEW IRELAND
NEW BRITAIN
SOLOMON Is
Port Moresby
MELANESIA
GILBERT Is
PHOENIX Is
ELLICE Is
TOKELAU Is
SAMOA
Santa Cruz Is
Banks Is
NEW HEBRIDES
FIJI Is
TONGA
NEW CALEDONIA
LOYALTY Is
QUEENSLAND
AUSTRALIA
Brisbane
NEW SOUTH WALES
Sydney
PACIFIC OCEAN
Norfolk I.
NEW ZEALAND
NOT TO SCALE
Scale of Miles
0 2 4 6 8 10 20 30 40
177°
178°
Longitude East 179°

INDEX TO SPECIES

(* denotes synonym or homonym)

Genus *Conus* Linnaeus, 1758

Type species: *Conus marmoreus* Linnaeus, 1758 - by subsequent designation Children, 1823 (Quart. Journ. Sci. Lit. Arts, **16**: 69).

Characteristics: Shell conical, turbinated and multispiral, columella smooth, aperture long and narrow, outer lip thin; periostracum thick or thin, smooth or ridged, covering entire shell with exception of aperture; operculum small, narrow, pointed and corneous.

DESCRIPTION of SPECIES

1. *Conus acutangulus* Lamarck, 1810
(Plate 17, Figure 54)

1810. *Conus acutangulus* Lamarck, Ann. Mus. Hist. Nat., **15**: 286

1857. *Conus acutangulatus* Sowerby, Thes. Conch. **3**: 11, pl. 16, fig. 356

1866. *Conus turriculatus* Sowerby, Thes. Conch. **3**: 328, pl. 27, figs. 643, 644 (non *C. turriculatus* Deshayes, 1865)

1870. *Conus gemmulatus* Sowerby, Proc. Zool. Soc. London, p. 257, pl. 22, fig. 8

1911. *Conus acutanculus,* Friedberg, Rozp. Wiadom Muzeum Imien. Dzied. (Moll. Mioc. Poloniae), **14**: 47

Shell: Shell small and fragile. Body whorl fawn to yellowish brown, with an irregular pattern of reddish-brown bands and lines, often arranged to form longitudinal streaks, leaving a light central transverse band; spiral ridges encircle the body whorl, and intervening grooves show a punctured pattern. Shoulder angulate, distinctly nodulose, spire high in proportion to shell length, concave, flecked with brown; whorls nodulose, striate, area between the spiral ridges and the upper whorl obliquely cancellate. Aperture narrow, lip thin and recurved, interior white or pale fawn.

Periostracum thin, smooth, translucent orange. The animal's foot is medium brown.

Type locality: Mers des grandes Indes.

H: 18 to 32 mm; W: 44 to 50%; HS: 26 to 36%; AA: 55° to 75°.

Habitat: From 2 to 15 fathoms, in sand. Rare.

Distribution: Mamanuca Group, West Viti Levu. - Philippines, Hawaii.

Discussion: *Conus eugrammatus* Bartsch & Rehder, 1943, was treated as a junior synonym by Kohn (1959, p. 372). Kohn & Weaver (1962) gave a detailed comparison of both species, convincingly demonstrating their valid specific separation.

2. *Conus ammiralis* Linnaeus, 1758
(Plate 13, Figure 24)

1758. *Conus ammiralis* Linnaeus, Syst. Nat., ed. 10, p. 713, no. 257

1767. *Conus vicarius* Linnaeus, Syst. Nat. ed. 12, p. 1167, no. 299

1798. *Cucullus imperialis* Röding, Mus. Bolten., p. 45 (non *Conus imperialis* Linnaeus, 1758)

1847. *Conus admiralis* [*sic*], Berge, Conchylienbuch, p. 234, pl. 40, fig. 12

1930. *Leptoconus ammiralis temnes* Iredale, Mem. Qld. Mus. **10** (1): 80

Shell: Shell of medium size, solid and smooth. Body whorl reddish-brown to dark brown, with 3 to 5 moderately narrow, orange transverse bands; white trigonal maculations of varying sizes are scattered on the remaining area of the body whorl, intruding at times into the transverse bands. Shoulder angulate, smooth, spire concavely depressed, smooth, apex pointed. Aperture moderately wide, white within.

Periostracum orange-brown, moderately thick and opaque.

Type locality: Oc. Americae meridionalis [error].
H: 34 to 71 mm; W: 46 to 57%; HS: 14 to 18%; AA: 95° to 115°
Habitat: In patches of sand, shallow water. Rare.
Distribution: Throughout Fiji. - Indo-West Pacific.
Discussion: The species is extremely variable in pattern, and accordingly received a number of varietal names. *Conus vicarius* LINNAEUS had been placed in the synonymy of *C. ammiralis;* LINNAEUS' reference to ARGENVILLE's figure V, reproduced in KOHN (1963 b), leaves no doubt that it is one of the many individual or ecological forms of *C. ammiralis.*

3. *Conus arenatus* HWASS in BRUGUIÈRE, 1792
(Plate 14, Figure 27)

1792. *Conus arenatus* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 621
1798. *Cucullus arenosus* RÖDING, Mus. Bolten., p. 40
1859. *Conus arenarius* BRUGUIÈRE, HANLEY, Journ. Proc. Linn. Soc. Zool., **4**: 62
1891. *Conus armatus* SMITH, Proc. Zool. Soc. London, p. 402
1937. *Conus arenatus* var. *aequipunctata* DAUTZENBERG, Mém. Mus. Roy. Hist. Nat. Belg., **2** (18): pl. 1, fig. 2
1937. *Conus arenatus* var. *undata* DAUTZENBERG, Mem. Mus. Roy. Hist. Nat. Belg., **2** (18): pl. 1, fig. 3
1937. *Conus arenatus* var. *granulosa* HWASS, DAUTZENBERG, Mem. Mus. Roy. Hist. Nat. Belg., **2** (18): pl. 1, fig. 4

Shell: Shell solid and broad. Body whorl white or cream, ornamented with numerous small brown spots, arranged in such a manner as to form irregular blotches and two to three transverse bands; base striate, striae often granulose. Shoulder rounded, coronate, spire low and slightly concave or straight, whorls striate. Aperture slightly ventricose, widening basally, interior white.
Type locality: Philippines.
H: 25 to 60 mm; W: 55 to 64%; HS: 10 to 14%; AA: 105° to 125°
Habitat: In sand, in shallow water. Common.
Distribution: Throughout Fiji. - Indo-West Pacific.
Discussion: Coronations are often obsolete in large adult specimens, and occasionally shells are found which are granulose from base to shoulder.

4. *Conus aristophanes* SOWERBY, 1857
(Plate 18, Figure 67)

1857. *Conus aristophanes* SOWERBY, Thes. Conch., **3**: 9, pl. 4, figs. 81, 82

Shell: Shell small, solid. Body whorl grey to greenish-grey, ornamented with two bluish-white transverse bands at shoulder and middle of whorl; about 12 to 15 rows of white and brown short dashes encircle the body whorl and the basal ridges are pronounced and continuous. The pattern of the last whorl is interrupted by a few whitish longitudinal zigzag lines. Shoulder coronate, often obsoletely nodulose in large mature specimens, with intervening spaces flecked dark brown; spire moderately low, nodulose, straight, often eroded. Each whorl bears one to two distinct spiral ridges. Aperture slightly narrow, fairly parallel to body whorl, margin of interior of aperture whitish, remainder violet-grey with a light median band.

Periostracum thin, smooth, translucent yellow.

Type locality: Philippines and Sandwich Islands [latter locality incorrect].
H: 15 to 37 mm; W: 60 to 67%; HS: 12 to 18%; AA: 105° to 125°
Habitat: Under dead coral on sandy substrate, and in sand patches, in shallow water. Common.
Distribution: Throughout Fiji. - Pacific.
Discussion: The species is usually associated with *Conus coronatus* GMELIN, 1791, but it is clearly separable as a species. The table below shows the more important morphological characteristics of the two species.

	Conus coronatus	*Conus aristophanes*
Shape:	ventricose, greatest width below shoulder	conical, greatest width at shoulder
Aperture:	flaring, wide and ventricose	slightly narrow, fairly parallel to body whorl
Spire:	elevated	rather depressed
Pattern:	brown to blackish-brown blotches on body whorl	blotches absent, light-coloured bands at shoulder and center
Coronations:	sharply cut, rarely obsolete	nodulose, often obsolete
Spiral ridges between whorls:	5 to 7 fine and well defined	1 to 2 broad, coarse
Basal ridges:	strong and interrupted	strong and continuous

5. *Conus aulicus* Linnaeus, 1758
(Plate 13, Figure 18)

1758. *Conus aulicus* Linnaeus, Syst. Nat. ed 10, p. 717, no. 279
1792. *Conus auratus* Hwass in Bruguière, Encycl. Méth. Vers, 1: 740
1798. *Cucullus aureus* Röding, Mus. Bolten., p. 49 (non *Conus aureus* Hwass in Bruguière, 1792)
1834. *Conus roseus* Sowerby, Conch. Illust., pt. 55, fig. 71 (non *Conus roseus* Fischer, 1807, non *Conus roseus* Lamarck, 1810)

Shell: Shell large, elongate, solid. Body whorl brown to dark reddish-brown, ornamented with white trigonal maculations of varying sizes, arranged obliquely to the body whorl; the white pattern tends to form transverse zones at the shoulder, center and base. Spiral striae are distinct at the base, becoming obsolete towards the shoulder. Shoulder rounded, smooth, spire elevated, fairly straight, maculated with brown; whorls striate. Aperture wide, flaring basally, interior yellowish-pink or pale orange.

Periostracum thin, smooth, translucent orange.

Type locality: Asia.

H: 73 to 144 mm; W: 35 to 42%; HS: 12 to 17%
AA: 70° to 90°

Habitat: Under dead coral on sandy substrate, in deeper water, occasionally in shallow water.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: The species has a venomous bite and should be handled with care; Kohn (1963) reported one case of poisonous sting, but it did not prove fatal.

6. *Conus aureus* Hwass in Bruguière, 1792
(Plate 13, Figure 22)

1792. *Conus aureus* Hwass in Bruguière, Encycl. Méth. Vers, 1: 742

Shell: Shell elongate-cylindrical. Body whorl orange to dark rusty brown, ornamented with numerous small and fine triangular white spots, arranged to form three transverse bands, and two or three longitudinal bands; the exposed orange or reddish-brown areas are marked with blackish-brown wavy longitudinal streaks. Fine transverse striae encircle the body whorl from base to shoulder. Shoulder rounded, smooth, spire elevated, slightly concave to straight, maculated with orange and white, and axially curved dark orange lines; apex pointed and white, whorls obsoletely striate. Aperture narrow, white within.

Type locality: China.

H: 25 to 62 mm; W: 38 to 44%; HS: 15 to 21%; AA: 80° to 90°

Habitat: Under dead coral on sandy substrate, in shallow and deeper water.

Distribution: North and South Viti Levu. - Pacific.

7. *Conus balteatus* Sowerby, 1833
(Plate 16, Figure 49)

1833. *Conus balteatus* Sowerby, Conch. Illust., pt. 37, fig. 58
1849. *Conus primula* Reeve, Conch. Icon., Supplement, pl. 6, spec. 259

Shell: Shell small. Body whorl brown, ornamented with small bluish-white spots and one or two pale transverse bands at the shoulder and center; the shoulder band is occasionally absent in large adult specimens. The last whorl spirally striate, striae pronounced basally, becoming flatter and wider spaced towards the shoulder. Shoulder angulate, coronate, intervening space stained with pale lilac or pale brown; spire low to moderately elevated, straight, coronate, bluish-white. Whorls bear 6 to 8 fine spiral striae. Aperture narrow, parallel to body whorl, interior violet with a pale band near shoulder and center.

Periostracum pale brown, smooth, moderately thick. In juvenile specimens the shoulder band is pronounced and interrupted by longitudinal brown streaks.

Type locality: None.

H: 23 to 38 mm; W: 58 to 63 %; HS: 9 to 16%; AA: 110° to 145°

Habitat: Under dead coral in shallow water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: *Conus propinquus* Smith, 1877 appears to be closely related to *C. balteatus*; it differs from the latter by being generally smaller in size, with only 5 to 6 spiral

Explanation of Plate 12

Figure 1: *Conus leopardus* Röding. Fiji (x 0.3)
Figure 2: *Conus litteratus* Linnaeus. Fiji (x 0.45)
Figure 3: *Conus eburneus* Hwass. Fiji (x 1.0)
Figure 4: *Conus distans* Hwass. Fiji (x 0.45)
Figure 5: *Conus vexillum* Gmelin. Fiji (x 0.5)
Figure 6: *Conus radiatus* Gmelin. Fiji (x 0.7)
Figure 7: *Conus miles* Linnaeus. Fiji (x 0.7)
Figure 8: *Conus generalis* Linnaeus. Fiji (x 0.7)
Figure 9: *Conus marmoreus* Linnaeus. Fiji (x 0.5)
Figure 10: *Conus bandanus* Hwass. Fiji (x 0.5)
Figure 11: *Conus imperialis* Linnaeus. Fiji (x 0.5)
Figure 12: *Conus striatus* Linnaeus. Fiji (x 0.6)
Figure 13: *Conus terebra* Born. Fiji (x 0.6)
Figure 13a: *Conus terebra* Born, juvenile specimen. Fiji (x 1.5)
Figure 14: *Conus figulinus* Linnaeus. Fiji (x 0.6)

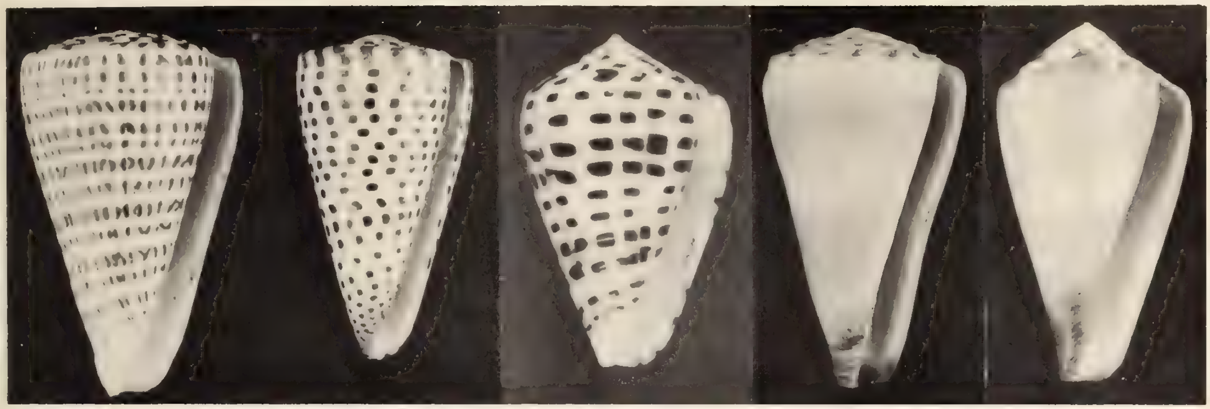


Figure 1 Figure 2 Figure 3 Figure 4 Figure 5

Figure 6 Figure 7 Figure 8 Figure 9 Figure 10

Figure 11 Figure 12 Figure 13 Figure 13 a Figure 14

photo. W. Cernohorsky

striae between whorls, having more rounded and wider spaced coronations on the shoulder, numbering 10 on the average, in comparison to 13 in *C. balteatus*. The basal extremity and a small area immediately above it are bluish white in *C. propinquus*, but constantly brown in *C. balteatus*.

8. *Conus bandanus* Hwass in Bruguière, 1792

(Plate 12, Figure 10)

1792. *Conus bandanus* Hwass in Bruguière, Encycl. Méth. Vers, **1**: 611

Shell: The species closely resembles *Conus marmoreus* Linnaeus, 1758, in shape, sculpture and general pattern; it differs in that the white triangular markings are smaller and more numerous, and are arranged in such a fashion as to form two distinct black narrow transverse bands on the body whorl. The triangular white markings are bordered with orange-brown, a feature absent in *C. marmoreus*.

Periostracum smooth, yellowish-brown, moderately translucent.

Type locality: Banda Island (Moluccas).

H: 46 to 88 mm; W: 52 to 59%; HS: 9 to 18%; AA: 120° to 140°

Habitat: On sandy substrate in deeper water. Rare.

Distribution: Mamanuca group, West Viti Levu. - Indo-West Pacific.

Discussion: Tomlin (1937) and Kira (1959) list *Conus bandanus* as a good species, while other writers regard it to be a form of *C. marmoreus*. The two species are clearly separable in Fiji, and intermediate specimens are not known. *Conus bandanus* has never been collected in shallow water in Fiji, whereas *C. marmoreus* is a common intertidal species.

9. *Conus bullatus* Linnaeus, 1758

(Plate 13, Figure 21)

1758. *Conus bullatus* Linnaeus, Syst. Nat., ed. 10, p. 717, no. 281

1798. *Cucullus parvus* Röding, Mus. Bolten., p. 46

1798. *Cucullus laganum* Röding, Mus. Bolten., p. 51

Shell: Shell cylindrically-ovate, rather solid. Body whorl white or bluish-white, ornamented with orange-brown or reddish-brown irregular, somewhat subtrigonal splotches; the reddish-brown markings tend to merge and form 2 to 3 ill-defined, broad transverse bands. The white or bluish-white base colour is exposed in the form of nebulous subtrigonal spots; the base bears widely spaced punctured grooves, while the remaining area of the body whorl appears glossy and smooth. Under close scrutiny, extremely fine and close-set spiral striae are discernible, and these extend as far as the shoulder; the maximum width of the shell is about one third of the length below the shoulder. Shoulder rounded, smooth, spire very low, concave, alternately flecked with pink and reddish-brown; whorls canaliculate, striate and axially cancellate. Aperture wide, flaring basally, interior orange with a broad pink marginal area.

Type locality: None.

H: 45 to 66 mm; W: 46 to 53%; HS: 5 to 10%; AA: 115° to 130°

Habitat: Deep water, on sandy substrate. Very rare.

Distribution: Known only from Yanuca Island, South Viti Levu. - Pacific.

10. *Conus capitaneus* Linnaeus, 1758

(Plate 14, Figure 30)

1758. *Conus capitaneus* Linnaeus, Syst. Nat., ed. 10, p. 713, no. 254

1792. *Conus classiarius* Hwass in Bruguière, Enc. Méth. Vers, **1**: 705

1817. *Conus chemnitzii* Dillwyn, Desc. cat. rec. shells, **1**: 363

1845 [?] *Conus blainvillei* Kiener, Spéc. Gén. Icon. Coq. Viv., p. 358, pl. 111, fig. 1

1858. *Conus ceciliae* Crosse, Journ. Conchyl., **7**: 381, pl. 14, fig. 5

Shell: Shell of medium size, fairly broad. Body whorl yellowish-brown to dark olive-brown, with two white transverse bands at shoulder and center; the central band is ornamented with dark brown blotches, while the shoulder band is longitudinally streaked with the same colour, and the streaks extend onto the spire. Interrupted dark brown lines encircle the body whorl, but may be absent in some specimens; spiral striae appear as widely separated ridges basally, and intervening striae show a punctured pattern. The base is stained with violet-brown. Shoulder angulate, broad and smooth, spire low, slightly concave, flecked with dark brown and white; whorls spirally striate. Aperture wide, angular at shoulder, interior violet.

Periostracum brown, transversely ridged, moderately thick.

Type locality: Asia.

H: 30 to 63 mm; W: 62 to 72%; HS: 5 to 11%; AA: 125° to 150°

Habitat: Under dead coral, in shallow and deeper water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: The angular and very broad shoulder, the great width in relation to shell length, and the dark brown blotches in the central band, readily separate this species from *Conus mustelinus* Hwass in Bruguière, 1792.

11. *Conus catus* Hwass in Bruguière, 1792
(Plate 15, Figure 42)

1792. *Conus catus* Hwass in Bruguière, Encycl. Méth. Vers, **1**: 707
1798. *Cucullus nubilus* Röding, Mus. Bolten., p. 46
1833. *Conus discrepans* Sowerby, Conch. Illust., pt. 29, fig. 28
1862. *Conus purus* Pease, Proc. Zool. Soc. London, p. 279 (Niihau Island)
1937. *Conus catus* var. *rubrapapillosa* Dautzenberg, Mém. Mus. Roy. Hist. Nat. Belg., **2** (18); pl. 1, fig. 7
1937. *Conus catus* var. *fuscoolivaceus* Dautzenberg, Mém. Mus. Roy. Hist. Nat. Belg., **2** (18); pl. 1, fig. 8

Shell: Shell small, bulbous and solid. Body whorl either dark brown, maculated with irregular white blotches, or white and ornamented with dark brown or reddish-brown blotches and spots; occasional specimens bear interrupted brown transverse lines on the body whorl. Spiral striae ridged and granulose basally, usually becoming obsolete towards the shoulder, although some specimens are granulose all over. Shoulder rounded, smooth, spire straight to convex, apex nipple-like if not eroded; whorls distinctly striate. Aperture moderately wide, interior white with a brown marginal edge.

Periostracum thin, smooth, translucent yellowish-brown.

Type locality: St. Domingue, Martinique, Île de France (Mauritius) [The first two localities are most probably erroneous.]

H: 20 to 50 mm; W: 55 to 65%; HS: 12 to 23%; AA: 85° to 115°

Habitat: Under dead coral on sand or reef substrate, in shallow water. Uncommon.

Distribution: West and South Viti Levu. - Indo-West Pacific.

Discussion: The species is piscivorous in nature (Kohn, 1963).

12. *Conus chaldaeus* (Röding, 1798)
(Plate 18, Figure 70)

1798. *Cucullus chaldaeus* Röding, Mus. Bolten., p. 42
1810. *Conus vermiculatus* Lamarck, Ann. Mus. Hist. Nat., Paris, **15**: 34

Shell: The species resembles *Conus ebraeus* Linnaeus, 1758; apart from being generally slightly smaller in size, *C. chaldaeus* has such close-set longitudinal flammules, that the white or ivory base colour appears in the form of longitudinal wavy white lines and two narrow transverse bands at the shoulder and center.

Periostracum thin, smooth and translucent yellow.

Type locality: None. ("Seas of Asia," Lamarck, 1810)

H: 18 to 41 mm; W: 55 to 66%; HS: 18 to 25%; AA: 100° to 120°

Habitat: In crevices of coral benches, close to the shore. Rare.

Distribution: Throughout Fiji. - Indo-Pacific to Clipperton and Galápagos Islands.

Discussion: The name of this species is frequently misspelled *Conus chaldeus* in literature. Fiji specimens of *C. chaldaeus* and *C. ebraeus* appear consistently different, and intermediate specimens have not been recorded.

13. *Conus circumactus* Iredale, 1929
(Plate 14, Figure 33)

1822. *Conus cinctus* Swainson, Zool. Illust., ser. **1** (2), pl. 110 [non *Conus cinctus* Bosc, 1801, non *C. cinctus* Link, 1807]
1822. *Conus pulchellus* Swainson, Zool. Illust., ser. **1** (2), pl. 114 [non *Cucullus pulchellus* Röding, 1798]
1929. *Conus circumactus* Iredale, Mem. Qld. Mus., **9**: 281 [nom. nov. pro *Conus cinctus* Swainson, 1822]
1943. *Conus hammatus* Bartsch & Rehder, Proc. Biol. Soc. Washington **56**: 86
1959. *Conus circumactis* Iredale, Kohn, Pacif. Sci., **13**: 377 [incorrect subsequent spelling]

Explanation of Plate 13

Figure 15: *Conus quercinus* Solander. Fiji (x 0.6)
Figure 16: *Conus virgo* Linnaeus. Fiji (x 0.5)
Figure 17: *Conus emaciatus* Reeve. Fiji (x 0.8)
Figure 17a: holotype of *Conus emaciatus* Reeve (38mm x 20mm) from the British Museum (Natural History). Re-photographed from original colour photograph taken by Dr. A. Kohn.
Figure 18: *Conus aulicus* Linnaeus. Fiji (x 0.4)
Figure 19: *Conus omaria* Hwass. Fiji (x 0.75)
Figure 20: *Conus episcopus* Hwass. Fiji (x 0.8)
Figure 21: *Conus bullatus* Linnaeus. Yanuca Island, Fiji (x 0.75)
Figure 22: *Conus aureus* Hwass. Fiji (x 0.70)
Figure 23: *Conus textile* Linnaeus. Fiji (x 0.65)
Figure 24: *Conus ammiralis* Linnaeus. Fiji (x 0.75)
Figure 25: *Conus retifer* Menke. Fiji (x 0.7)
Figure 26: *Conus tessulatus* Born. Fiji (x 1.0)

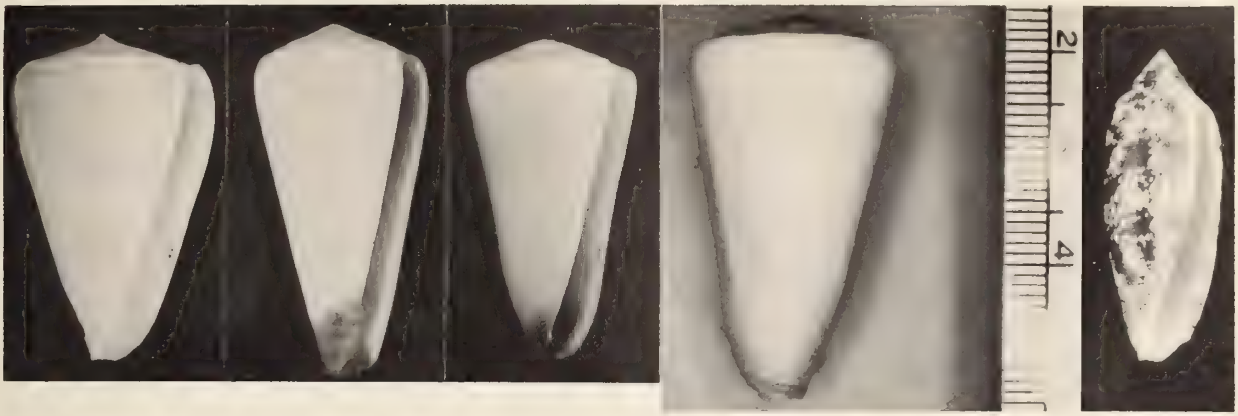


Figure 15 Figure 16 Figure 17 Figure 17 a Figure 18

Figure 19 Figure 20 Figure 21

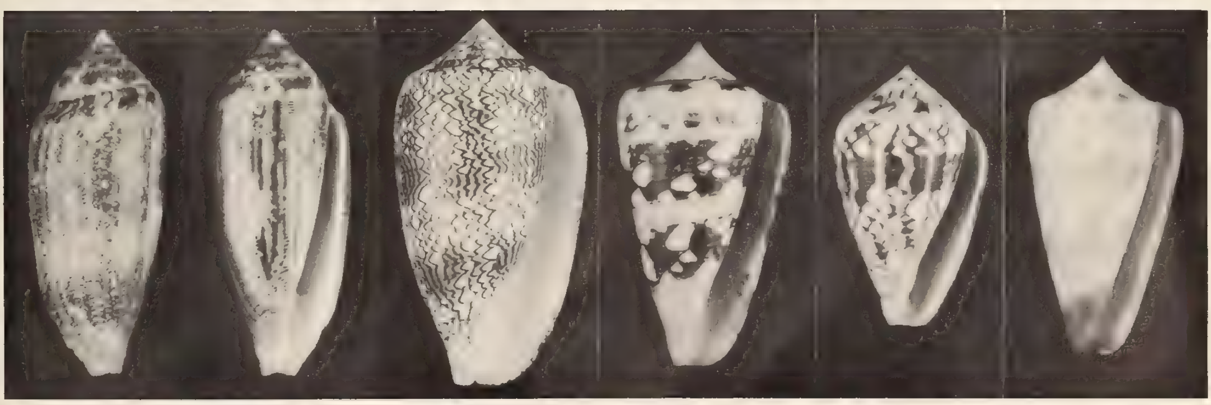


Figure 22 Figure 23 Figure 24 Figure 25 Figure 26

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Shell: Shell of medium size, fairly solid. Body whorl yellow or orange-brown, with large white blotches arranged in bands at the shoulder and centrally on body whorl; thin brown lines, often interrupted, encircle the shell. Base and lower part of aperture stained with pink, occasionally violet-pink; body whorl transversely striate, spiral ridges basally granulose, becoming obsolete towards the shoulder. Shoulder sharply angled, smooth, spire low, whitish or pink and flecked with brown; whorls striate. Aperture narrow, fairly parallel to body whorl, interior pinkish-white.

Type locality: Amboina.

H: 15 to 55 mm; W: 50 to 57%; HS: 9 to 16%; AA: 105° to 130°

Habitat: On sand substrate in deeper water, occasionally in shallow water. Rare.

Distribution: North and East Viti Levu. - Pacific.

Discussion: The holotype of *Conus hammatus* BARTSCH & REHDER is a juvenile specimen of *C. circumactus* (*fide* KOHN, 1959). TOMLIN (1937) stated that the holotype of *C. connectens* A. ADAMS, 1855, is identical with *C. circumactus*. Should TOMLIN's assumption prove to be correct, *C. connectens* A. ADAMS would have priority over *C. circumactus* IREDALE. ADAM's type specimen appears to be a large (54 mm), beach-worn, faded creamy-yellow shell with faint remnants of two broad reddish-orange transverse bands. I hesitate to associate this shell with *C. circumactus*.

14. *Conus coronatus* GMELIN, 1791
(Plate 18, Figure 68)

1778. *Conus minimus* BORN, Test. Mus. Caes. Vindob., p. 156 [non *Conus minimus* LINNAEUS, 1758]
1791. *Conus coronatus* GMELIN, Syst. Nat., ed. 13, p. 3389
1798. *Cucullus coronalis* RÖDING, Mus. Bolten., p. 38
1864. *Conus minimus* var. *condoriana* CROSSE & FISCHER, Journ. Conchyl., **12**: 334

Shell: Shell small, bulbous, and solid. Body whorl white, fawn or pale brown, with brown or blackish-brown splotches of various sizes and white irregular streaks; transverse rows of small brown dots and spiral striae encircle the body whorl; striae at base and part of the whorl raised and distinctly granulose. Shoulder coronate, spire elevated, nodulose, flecked with brown; whorls bear 5 to 7 fine, well defined spiral striae. The maximum width of the shell is reached below the shoulder. Aperture wide and bulbous, interior purplish-grey with a whitish median band and marginal edge.

Periostracum thin, smooth, translucent pale orange.

Type locality: None. ("In Indiis," BORN, 1778).

H: 15 to 33 mm; W: 60 to 67%; HS: 16 to 24%; AA: 80° to 110°

Habitat: Under coral on sand substrate and sand pockets, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

15. *Conus cylindraceus* BRODERIP & SOWERBY, 1830
(Plate 17, Figure 58)

1830. *Conus cylindraceus* BRODERIP & SOWERBY, Zool. Journ. London, **5**: 51, Suppl. pl. 40, fig. 5

Shell: Shell narrow and cylindrical. Body whorl greyish-brown to reddish-brown, ornamented with longitudinal curved white lines extending from shoulder to base; white short streaks and dots are placed between these lines, and form an interrupted band at the shoulder and another one third above the base. Spiral striae are granulose at the base, becoming obsolete towards the shoulder. Shoulder hardly formed, smooth, spire extremely elevated and convex; each whorl bears a distinct spiral groove. Aperture narrow, parallel to body whorl, interior white.

Type locality: None.

H: 20 to 30 mm; W: 32 to 40%; HS: 28 to 34%; AA: 40° to 55°

Habitat: Dredged from deeper water. Very rare.

Distribution: West Viti Levu. - Pacific.

16. *Conus dilectus* GOULD, 1850
(Plate 17, Figure 62)

1850. *Conus dilectus* GOULD, Proc. Boston Soc. Nat. Hist., **3**: 172, Exped. shells, fig. 367

Shell: Shell very small, narrow and conical. Body whorl pale red to reddish-brown, irregularly spotted with white to form one faint band arrangement below the shoulder, and another central transverse band composed of irregular white longitudinal wavy blotches. Base spirally ridged, striae becoming obsolete towards the shoulder; minute brown spots are situated on top of the spiral ridges. Shoulder angulate, obsoletely coronate, spire elevated, straight to slightly concave, nodulose, apex pointed; early whorls pale orange, last two whorls whitish, maculated with rather triangular blackish-brown blotches. Each whorl bears two distinct spiral ridges. Aperture narrow, straight, interior delicate rose colour.

Periostracum thin, smooth, translucent yellow.

Type locality: Feejee Islands (Fiji Islands).

H: 11 to 13 mm; W: 48 to 51%; HS: 18 to 22% AA: 85° to 95°

Habitat: In sand patches of coral reefs, in shallow and deep water. Very rare.

Distribution: Restricted to North Viti Levu.

Discussion: GOULD's description, type figure and size

quoted for the type specimen (Long: ½", Lat: ¼") agree well with Fiji specimens.

17. *Conus distans* Hwass in Bruguière, 1792
(Plate 12, Figure 4)

1792. *Conus distans* Hwass in Bruguière, Encycl. Méth. Vers, 1: 634

Shell: Shell large and thick. Body whorl pale yellowish-brown or fawn, smooth, with two whitish transverse bands at the shoulder and center; base stained purplish-brown. Shoulder angulate, coronate, coronations white, intervening spaces stained dark brown; spire low, tuberculate. Aperture narrow, slightly waisted, fairly parallel to body whorl; interior pale violet, stained dark violet basally.

Periostracum greenish-brown, thick, ridged and tufted.

Type locality: Coast of New Zealand [error].

H: 51 to 90 mm; W: 52 to 59%; HS: 7 to 15%; AA: 125° to 145°

Habitat: In patches of sand, among weed, in shallow and deeper water. Uncommon in the South, rare in North Viti Levu.

Distributon: West, South and North Viti Levu. - Indo-West Pacific.

18. *Conus ebraeus* Linnaeus, 1758
(Plate 18, Figure 69)

1758. *Conus ebraeus* Linnaeus, Syst. Nat., ed. 10, p. 715, no. 268

1778. *Conus hebraeus* Born, Test. Mus Caes. Vindob., p. 159

1811. *Conus quadratus* Perry, Conchology, pl. 24, fig. 5 [non *Cucullus quadratus* Röding, 1798]

Shell: Shell conical and solid. Body whorl white or cream, ornamented with blackish-brown, trapezoidal blotches, arranged longitudinally to form 3 to 4 transverse, interrupted bands; base spirally ridged, often granulose. Shoulder angulate, coronate, spire moderately elevated, subcoronate, symmetrically flecked with blackish-brown and white; whorls finely striate. Aperture narrow, interior violet-brown, with a light median band.

Periostracum thin, smooth, translucent yellow.

Type locality: India.

H: 16 to 45 mm; W: 57 to 62%; HS: 15 to 21%; AA: 100° to 125°

Habitat: In crevices of coral benches close to shore. Common.

Distribution: Throughout Fiji. - Indo-West Pacific to Clipperton and Galápagos Islands.

Discussion: The species is frequently misspelled *Conus hebraeus* in literature.

19. *Conus eburneus* Hwass in Bruguière, 1792
(Plate 12, Figure 3)

1792. *Conus eburneus* Hwass in Bruguière, Encycl. Méth. Vers, 1: 640

1858. *Conus crassus* Sowerby, Thes. Conch., 3: 25, figs. 254, 255 (Hab: Fiji Islds.)

Shell: Shell conical and solid. Body whorl white, ornamented with transverse rows of blackish-brown bars and rectangular blotches; two to four yellow or orange, narrow transverse bands encircle the body whorl, but are occasionally absent. Base spirally striate. Shoulder angulate, smooth, spire elevated or almost flat, concave, white flecked with blackish-brown; whorls bear two spiral striae. Aperture narrow, fairly straight, interior white.

Periostracum smooth, orange-brown and opaque in adults, yellowish-orange and translucent in juvenile specimens.

Type locality: East Indies.

H: 12 to 62 mm; W: 62 to 67%; HS: 5 to 14%; AA: 110° to 160°

Habitat: Among weed, on sand substrate, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: The species is extremely variable in respect to the height of the spire, density and arrangement of the blackish-brown bars and blotches, and the number of yellow transverse bands. *Conus crassus* Sowerby appears to be an individual aberrant, sporadically occurring in large populations of *C. eburneus* in Fiji.

20. *Conus emaciatus* Reeve, 1849
(Plate 13, Figures 17, 17 a)

1849. *Conus emaciatus* Reeve, Conch. Icon., Suppl., pl. 5, spec. 248

Shell: Shell slightly elongate. Body whorl orange or orange-yellow, with two pale yellow transverse bands at shoulder and mid-area; body whorl encircled by widely

Explanation of Plate 14

Figure 27: *Conus arenatus* Hwass. Fiji (x 0.85)
Figure 28: *Conus pulicarius* Hwass. Fiji (x 0.7)
Figure 29: *Conus planorbis* Born. Fiji (x 0.75)
Figure 29a: *Conus planorbis* Born, yellow, granulose variant. Fiji (x 1.0)
Figure 30: *Conus capitaneus* Linnaeus. Fiji (x 0.75)
Figure 31: *Conus mustelinus* Hwass. Fiji (x 0.65)
Figure 32: *Conus vitulinus* Hwass. Fiji (x 0.85)
Figure 33: *Conus circumactus* Iredale. Fiji (x 1.0)
Figure 34: *Conus striatellus* Link. Fiji (x 1.0)
Figure 35: *Conus varius* Linnaeus. Fiji (x 0.65)

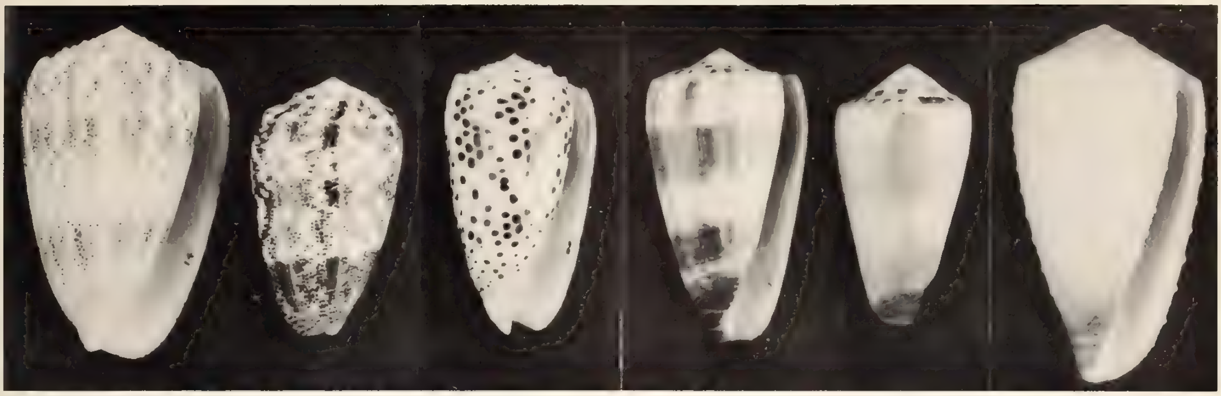

Figure 27 Figure 28 Figure 29 Figure 29 a

Figure 30 Figure 31 Figure 32

Figure 33 Figure 34 Figure 35

photo. W. Cernohorsky

spaced spiral striae, which become obsolete at the shoulder. The left side of the shell is slightly concave towards the anterior end, and the base and anterior portion of aperture are stained with purple. Shoulder angulate, smooth, spire depressed, often flat and eroded, yellow in colour, becoming creamy-white towards the apex; whorls finely striate. Aperture narrow, waisted centrally, slightly broadening anteriorly; interior pinkish-white, with an orange marginal edge.

Periostracum dark brown, smooth and thick. Juvenile specimens are dark orange or orange-brown, have well defined and granulose spiral striae, and the interior of the aperture is violet.

Type locality: Philippine Islands.

H: 24 to 56 mm; W: 50 to 61%; HS: 5 to 12%; AA: 120° to 170°

Habitat: In crevices of coral boulders, on reef substrate, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: TOMLIN (1937), COTTON (1945) and DODGE (1953) considered this species synonymous with *Conus virgo* LINNAEUS, 1758. TOMLIN (*l. c.*) stated that REEVE's holotype, preserved in the British Museum, was a *C. virgo*; a colour photograph of REEVE's type specimen, kindly made available to me by Dr. Kohn, shows REEVE's type to be a typical *C. emaciatus*. Specimens of both species with preserved animals, collected by the author in Fiji, were forwarded to Dr. Kohn for study of the soft parts. Dr. Kohn (personal communication) found the radular teeth of *C. emaciatus* to resemble those of *C. flavidus* LAMARCK more closely than those of *C. virgo* or *C. frigidus* REEVE.

The more important morphological characteristics of both species are given in the table below.

21. *Conus episcopus* HWASS in BRUGUIÈRE, 1792
(Plate 13, Figure 20)

1792. *Conus episcopus* HWASS in BRUGUIÈRE, Encycl. Méth. Vers., **1**: 748, var. β

1937. *Conus episcopus* var. *elongata* DAUTZENBERG, Mém. Mus. Roy. Hist. Nat. Belg., **2** (18), pl. 3, fig. 7

Shell: Shell elongate and narrow. Body whorl dark brown, ornamented with large white irregularly trigonal blotches, often arranged to form 3 ill-defined transverse and longitudinal bands; the brown areas are flecked with small white spots. The body whorl is finely transversely striate from base to shoulder. Shoulder rounded and sloping, smooth, spire straight to slightly concave, but short in relation to shell length, apex obtusely rounded; whorls smooth. Aperture narrow, interior white.

Periostracum thin, smooth, translucent yellowish-brown.

Type locality: Grandes Indes.

H: 40 to 70 mm; W: 40 to 46%; HS: 10 to 16%; AA: 80° to 110°

Habitat: Under coral on sand substrate, or buried in sand. Rare.

	Conus virgo	*Conus emaciatus*
Length:	38 to 150 mm	24 to 56 mm
Width:	50% to 59%	50% to 61%
Body whorl in adults:	creamy-white, spiral striae distinct at base, but obsolete elsewhere, striae cease abruptly at aperture	orange, widely spaced spiral striae from base to just below shoulder, striae continue inside the aperture, body whorl with two light bands
Spire:	slightly elevated, concave first whorl channeled near shoulder, maximum width just below the shoulder	low, often flat and eroded, whorls finely striate, maximum width at shoulder
Juvenile specimens:	yellow to orange, spiral striae on body whorl close-set, obsolete inside of aperture	dark orange-brown, with pronounced spiral granulose ridges from base to shoulder
Lip of aperture:	straight, occasionally slightly waisted	distinctly waisted
Habitat:	in sand	in crevices and under coral

Distribution: West and South Viti Levu. - Indo-West Pacific.

22. *Conus figulinus* LINNAEUS, 1758
(Plate 12, Figure 14)

1758. *Conus figulinus* LINNAEUS, Syst. Nat., ed. 10, p. 715, no. 267
1798. *Cucullus buxeus* RÖDING, Mus. Bolten., p. 42
1845. *Conus loroisii* KIENER, Spéc. Gén. Icon. Coq. Viv., 2: 91, pl. 65, fig. 1
1883. *Conus figulinus* var. *chytreus* TRYON, Man. Conch., 6: 17, pl. 27, fig. 1
1933. *Conus figulinus* var. *violascens* BARROS & CUNHA, Mem. Estud. Mus. Zool. Univ. Coimbra, ser. 1, no. 71, p. 37
1937. *Conus figulinus* var. *insignis* DAUTZENBERG, Mém. Mus. Roy. Hist. Nat. Belg., 2 (18), pl. 1, fig. 6 [non *C. insignis* SOWERBY, 1833]

Shell: Shell large, solid, pyriform. Body whorl light brown to dark tan in colour, ornamented with dark brown, continuous, close-set spiral lines; base spirally striate, striae becoming obsolete towards the shoulder. Shoulder rounded, smooth, spire depressed, convex; early whorls acuminate. Aperture straight, moderately narrow, interior white.
Type locality: None.
H: 42 to 97 mm; W: 56 to 65%; HS: 10 to 15%; AA: 110° to 130°
Habitat: Among weed, on sand substrate, in shallow and deeper water. Rare.
Distribution: West, South and East Viti Levu. - Indo-West Pacific.

23. *Conus flavidus* LAMARCK, 1810
(Plate 16, Figure 48)

1810. *Conus flavidus* LAMARCK, Ann. Mus. Hist. Nat., Paris, 15: 265
1860. *Conus neglectus* PEASE, Proc. Zool. Soc. London, pt. 28, p. 398 [non *C. neglectus* A. ADAMS, 1853]
1877. *Lithoconus peasei* BRAZIER, Proc. Linn. Soc. New South Wales, 1: 288 [nom. nov. pro *Conus neglectus* PEASE, 1860]

Shell: Shell of medium size, thick. Body whorl orange-brown to reddish-brown, with two white or bluish-white transverse bands at the shoulder and center; base spirally ridged, ridges often granulose, becoming obsolete past the central band towards the shoulder. Base stained with dark violet. Shoulder angulate, smooth, spire low to moderately elevated, white or bluish-white, slightly canaliculate, but often eroded; whorls obsoletely striate. Aperture narrow, lip thin, interior dark violet with a pale median band, marginal edge orange.

Periostracum dark grey, smooth and thick in adults, transversely ridged and thinner in juvenile specimens.

Egg capsules are small and oval, ridged, pale pink in colour; capsules measured approximately 8.5 mm in height and 6.5 mm in maximum width; they were deposited on the substrate in parallel rows.
Type locality: None.
H: 28 to 61 mm; W: 54 to 63%; HS: 6 to 13%; AA: 115° to 150°
Habitat: Under dead coral, on reef substrate and in crevices of shelving coral reef benches, in shallow water. Common.
Distribution: Throughout Fiji. - Indo-West Pacific.

24. *Conus frigidus* REEVE, 1848
(Plate 16, Figure 47)

1848. *Conus frigidus* REEVE, Conch. Icon., Suppl., pl. 3, spec. 284

Shell: Shell solid, thick. Body whorl fawn to yellowish-brown, with two pale fawn transverse bands at shoulder and center; base spirally striate, striae distinctly ridged and granulose at base, becoming less pronounced towards the shoulder. Base stained with violet. Shoulder slightly rounded, smooth, spire moderately elevated, straight, fawn in colour, often eroded; apex pale violet, whorls with 3 to 4 distinct spiral threads. Aperture narrow, lip thick, interior violet, with a pale median band, and occasionally a pale oval area on the lower half.

Periostracum dark greyish-brown, smooth, thick.
Type locality: None.
H: 30 to 50 mm; W: 57 to 64%; HS: 7 to 15%; AA: 110° to 130°

Explanation of Plate 15

Figure 36: *Conus scabriusculus* DILLWYN. Fiji (x 0.8)
Figure 37: *Conus geographus* LINNAEUS. Fiji (x 0.45)
Figure 38: *Conus tulipa* LINNAEUS. Fiji (x 0.7)
Figure 39: *Conus spectrum* LINNAEUS. Fiji (x 1.0)
Figure 40: *Conus obscurus* SOWERBY. Fiji (x 1.25)
Figure 41: *Conus magus* LINNAEUS. Fiji (x 0.8)
Figure 42: *Conus catus* HWASS. Fiji (x 0.9)
Figure 43: *Conus achatinus* GMELIN. Darwin, North Australia (x 0.7)
Figure 44: *Conus* cf. *C. vinctus* ADAMS. Fiji (x 1.25)
Figure 44a: *Conus* cf. *C. vinctus* ADAMS. Sulu Sea, Philippine Islands (x 1.0)
Figure 45: *Conus* species. Fiji (x 0.75)
Figure 45a: *Conus* species, Batangas Bay, Luzon, Philippine Islands (x 0.7)

Figure 36 Figure 37 Figure 38 Figure 39

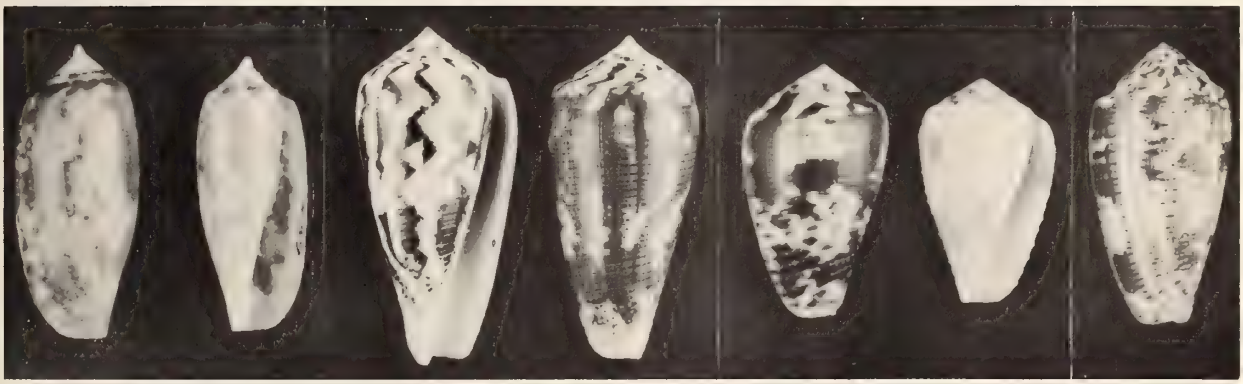

Figure 40 Figure 41 Figure 42 Figure 43

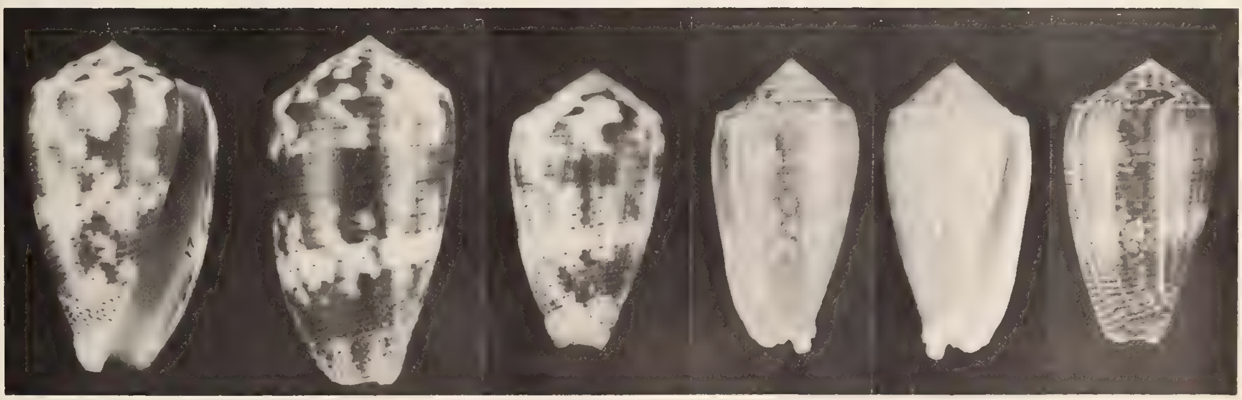

Figure 44 Figure 44 a Figure 45 Figure 45 a

photo. W. Cernohorsky

Habitat: Under dead coral, on reef substrate, in shallow water. Uncommon.

Distribution: West and South Viti Levu. - Indo-West Pacific.

Discussion: *Conus flavidus* LAMARCK, which is closely related to *C. frigidus*, usually lacks the spiral ridges on the upper part of the body whorl, and the transverse bands are white or bluish-white, not pale yellowish-fawn as in *C. frigidus;* the latter has a slightly rounded shoulder, distinctly striate whorls and a pale violet apex, features which distinguish it from *C. flavidus.* Dr. Kohn (personal communication) found the radula of *C. frigidus* to be separable from that of *C. flavidus.*

25. *Conus generalis* LINNAEUS, 1767
(Plate 12, Figure 8)

1758. *Conus capitaneus* var. *generalis* LINNAEUS, Syst. Nat., ed. 10, p. 713, no. 254
1767. *Conus generalis* LINNAEUS, Syst. Nat., ed. 12, p. 1166, no. 293
1792.[?]*Conus monile* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1:** 646
1798. *Cucullus cereolus* RÖDING, Mus. Bolten., p. 44
1798. *Cucullus dux* RÖDING, Mus. Bolten., p. 44 [non *Conus dux* HWASS in BRUGUIÈRE, 1792]
1798. *Cucullus ornatus* RÖDING, Mus. Bolten., p. 44
1798. *Cucullus locumtenens* RÖDING, Mus. Bolten., p. 45 [non *Conus locumtenens* BLUMENBACH, 1791]
1807. *Conus cinctus* LINK, Beschr. Nat. Samml. Univ. Rostock, Abt. 3, p. 102 [non *C. cinctus* BOSC, 1801]
1863. *Conus spirogloxus* DESHAYES, Conch. Île Reunion, p. 135, pl. 13, figs. 13, 14

Shell: Shell narrow, elongate. Body whorl reddish-brown to dark brown, ornamented with irregular, somewhat squarish white blotches, often fused together to form 3 white transverse bands at shoulder, center and base; extremely fine and close-set spiral striae extend from base to shoulder, base faintly stained with violet-brown. Shoulder sharply angulate, smooth, spire depressed, extremely concave, early whorls acuminate, slightly canaliculate. Aperture narrow, slightly waisted centrally, interior whitish, anteriorly stained dark violet-brown.

Periostracum dark grey, thick and smooth.

Type locality: India orientali.

H: 45 to 75 mm; W: 41 to 52%; HS: 7 to 12%; AA: 120° to 130°

Habitat: In patches of sand, under coral on sand substrate, in shallow water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: The white transverse bands will vary in width, and occasionally only one or two transverse zones are visible.

26. *Conus geographus* LINNAEUS, 1758
(Plate 15, Figure 37)

1758. *Conus geographus* LINNAEUS, Syst. Nat., ed. 10, p. 718, no. 283
1798. *Cucullus geographicus* RÖDING, Mus. Bolten., p. 39
1833. *Conus rosea* SOWERBY, Conch. Illust., pt. 32, fig. 33
1843. *Conus intermedius* REEVE, Conch. Icon., **1:** pl. 23, spec. 129 [non *Conus intermedius* LAMARCK. 1810]
1858. *Conus mappa* CROSSE, Rev. Mag. Zool., (2), **10:** 200 & 205 [non *Conus mappa* SOLANDER, 1786]

Shell: Shell large, thin. Body whorl pale brown to dark brown, ornamented with white or bluish-white, irregular trigonal or rhomboidal small blotches; these are arranged in such a manner as to form 2 to 4 transverse zones on the body whorl. Shoulder angulate, distinctly coronate, spire low, concave, whitish, flecked and axially lined with brown; apex pointed. Aperture very wide, flaring basally, lip thin, interior bluish-white.

Periostracum thin, smooth, translucent yellowish-orange.

Type locality: In Indiis.

H: 44 to 127 mm; W: 45 to 52 %; HS: 7 to 11%; AA: 110° to 125°

Habitat: Under coral on sand substrate, in deeper water; rarely collected in shallow water. Rare.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: The species is piscivorous in nature; it is extremely toxic and usually lethal to human beings. Nine cases of stinging have been recorded, and five of these resulted in death (KOHN, 1963).

27. *Conus glans* HWASS in BRUGUIÈRE, 1792
(Plate 17, Figure 60)

1792. *Conus glans* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1:** 735
1937. *Conus glans* var. *tenuigranulata* DAUTZENBERG, Mém. Mus. Roy. Hist. Nat. Belg., **2** (18), pl. 1, fig. 11

Shell: Shell small. Body whorl dark purplish-brown, with a central bluish-white transverse band, and occasionally another faint light band below the shoulder; shell distinctly concave near the base, ornamented with coarse, interrupted revolving ridges from base to shoulder. Shoulder rounded, smooth, spire elevated, slightly convex, pale purple, apex nipple-like; whorls with three pronounced spiral striae. Aperture bulbous, narrow near shoulder, but widening basally; interior of aperture purple.

Periostracum smooth, transversely minutely ridged, dark greyish-brown, thin and opaque.

Type locality: Africa.

H: 17 to 32 mm; W: 46 to 54%; HS: 18 to 21%; AA: 80° to 100°

Habitat: Under coral on reef substrate, in shallow water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

28. *Conus imperialis* Linnaeus, 1758
(Plate 12, Figure 11)

1758. *Conus imperialis* Linnaeus, Syst. Nat., ed. 10, p. 712, no. 251

1798. *Cucullus corona-ducalis* Röding, Mus. Bolten., p. 38

1798. *Cucullus regius* Röding, Mus. Bolten., p. 38 [non *Conus regius* Gmelin, 1791]

1810. *Conus viridulus* Lamarck, Ann. Mus. Hist. Nat. Paris, **15**: 31

1906. *Conus queketti* Smith, Ann. Natal Govt. Mus., **1**: 22, pl. 7, fig. 1

1933. *Conus imperialis nigrescens* Barros & Cunha, Mem. Estud. Mus. Zool. Univ. Coimbra, ser. 1, no. 71, p. 17 [non *C. nigrescens* Sowerby, 1859]

1933. *Conus imperialis flavescens* Barros & Cunha, Mem. Estud. Mus. Zool. Univ. Coimbra, ser. 1, no. 71, p. 18 [non *C. flavescens* Sowerby, 1834]

Shell: Shell large, solid, slightly elongate. Body whorl white or cream, ornamented with two broad, orange-brown transverse bands, the band below the shoulder being the broader; dark brown, interrupted lines composed of dashes and dots, encircle the body whorl. Shoulder angulate, distinctly coronate, spire low, often flat, apex rounded or eroded. Aperture narrow, lip thin, waisted centrally; interior white or bluish-white, basally stained with pale violet.

Periostracum smooth, orange, moderately thin.

Type locality: None.

H: 22 to 106 mm; W: 50 to 60%; HS: 1 to 9%; AA: 145° to 180°

Habitat: Under coral buried in sand, in sandy pockets of coral reefs, in shallow water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: This species feeds on polychaete annelids in nature (Kohn, 1963).

29. *Conus insculptus* Kiener, 1845
17 (Plate 16, Figures 55, 55 a)

1845. *Conus insculptus* Kiener, Spéc. Gén. Icon. Coq. Viv., p. 309, pl. 99, fig. 2

Shell: Shell small, fusiform, with a distinctly attenuated base. Body whorl fawn to pale brown, ornamented with two or three transverse bands, consisting of brown squarish blotches; shell sculptured with fairly close-set spiral grooves from base to shoulder, grooves being punctured and traversed by axial cancellations. Shoulder angled, smooth, spire very high, concave to straight, maculated with brown blotches; whorls are terraced, spirally finely striate, striae interrupted by close-set, fine axially curved lines. Aperture very narrow, lip thin and recurved, interior of aperture pink.

Type locality: La mer de Chine.

H: 16 to 34 mm; W: 36 to 43%; HS: 20 to 30%; AA: 55° to 75°

Habitat: Dredged from 15 fathoms, on sand and coral rubble bottom. Rare.

Distribution: Mamanuca group, West of Viti Levu. - Philippines.

Discussion: Fiji specimens compare favorably with Kiener's description and illustration, except for one or two points. Kiener describes the transverse grooves as "punctured," but fails to mention the close-set axial ridges inside the grooves, which characterize this species and which he uses describing *Conus aculeiformis* Reeve, 1844. He further mentions 8 whorls on the spire for this species, whereas Fiji specimens have 10 to 11 whorls. He also describes his *C. insculptus* as rusty-brown in colour throughout, a fact which applies to Philippine specimens of this species, but not to those from Fiji. Reeve (1849) illustrates and describes Kiener's *C. insculptus* as a shell with fine small coronations at the shoulder. *Conus insculptus*, however, is a non-coronate species.

Philippine specimens of *Conus insculptus* match Kiener's illustration and description very closely. Apart from the different colour pattern, Fiji specimens agree with those from the Philippines in form, sculpture and size, and hardly justify a specific separation.

Explanation of Plate 16

Figure 46: *Conus sugillatus* Reeve. Fiji (x 1.0)

Figure 47: *Conus frigidus* Reeve. Fiji (x 1.0)

Figure 48: *Conus flavidus* Lamarck. Fiji (x 0.85)

Figure 49: *Conus balteatus* Sowerby. Fiji (x 1.35)

Figure 50: *Conus lividus* Hwass. Fiji (x 0.85)

Figure 51: *Conus sanguinolentus* Quoy & Gaimard. Fiji (x 1.0)

Figure 51a: *Conus sanguinolentus* Quoy & Gaimard. Mauritius (x 1.0)

Figure 51b: *Conus sanguinolentus* Quoy & Gaimard. Formosa Bay, Kenya (x 1.0) photo. Dr. W. R. Barker.

Figure 52: *Conus moreleti* Crosse. Fiji (x 1.0)

Figure 46

Figure 47

Figure 48

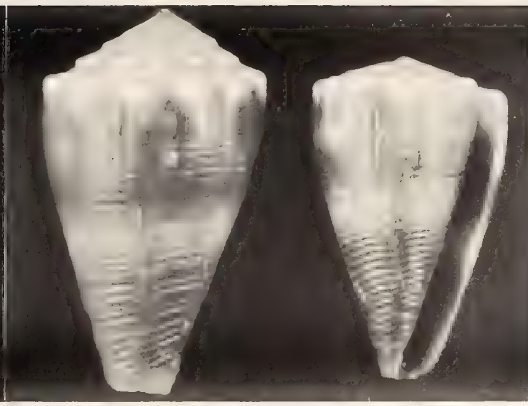

Figure 49

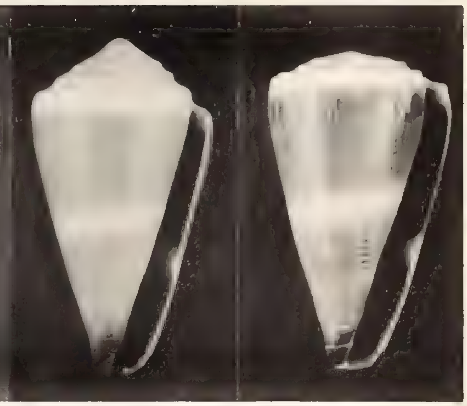

Figure 50

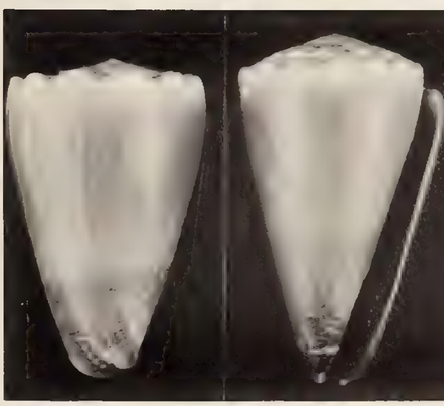

Figure 51

Figure 51 a

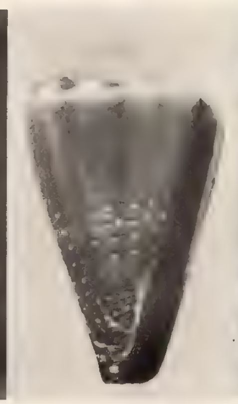

Figure 51 b

Figure 52

photo. W. Cernohorsky

30. *Conus lachrymosus* Reeve, 1849
(Plate 18, Figures 64, 66, 66 a, 66 b, 66 c, 66 d)

1849. *Conus lachrymosus* Reeve, Conch. Icon., Suppl., pl. 6, spec. 258
1849. *Conus rivularius* Reeve, Conch. Icon., Suppl., pl. 6, spec. 261

Shell: Shell small, moderately thin. Body whorl white, occasionally cream, ornamented with irregular yellow, orange or reddish-brown blotches and flammules; the design may be continuous from shoulder to base, or interrupted at the shoulder and center, to form two ill-defined, white transverse zones. Some specimens bear close-set transverse lines of dots of the same colour as the pattern, while other specimens lack this feature; the body whorl is transversely striate, striae often granulose at the base, becoming either obsolete or continuous towards the shoulder. Widely spaced reddish-brown spots are positioned on top of the spiral ridges at the base. Shoulder angulate, occasionally slightly rounded, obsoletely nodulose, rarely smooth, spire depressed, concave, or straight to slightly convex, white in colour with orange or brown maculations; apex raised and papillate, if not eroded. Whorls bear 3 to 4 spiral striae, and intervening spaces are axially cancellate. Aperture moderately narrow, lip thin, interior of aperture white or faintly pink.

Juvenile shells are white and waxen in appearance, with continuous longitudinal flammules from shoulder to base, and faint transverse rows of orange spots; the shoulder is distinctly angulate and spire extremely concave, the early whorls sub-coronate.

Periostracum thin, pinkish-orange to reddish-orange, moderately translucent, sometimes opaque, and transversely ridged and tufted.

Egg cases are very pale pink, oval in shape, well separated from each other; they measure approximately 6.5 mm in height, 4.8 mm in width and 1.6 mm in thickness.

Type locality: None. ("Moluccas" for *Conus rivularius*)
H: 12 to 25 mm; W: 48 to 57%; HS: 12 to 18%; AA: 90° to 115°

Habitat: Under coral, on sand and weed substrate, in shallow water. Moderately common in the Mamanuca group, West Viti Levu, but rare elsewhere.

Distribution: Throughout Fiji.

Discussion: Tomlin (1937) synonymized *Conus lachrymosus* and *C. rivularius* with *C. boeticus* Reeve, 1844. Reeve's type figure of *C. boeticus* shows a shell with a distinctly rounded and sub-coronate shoulder, and a very high, straight to slightly convex spire, and lacking the high, obtuse, nipple-like apex of Fiji specimens; Reeve's type figure measures about 37.5 mm, whereas the largest specimen collected in Fiji is only 24.8 mm in height. Reeve's type specimens, mounted on a tablet in the British Museum, are accompanied by note: "This is the true *adansonii* of Lamarck" (*fide* Tomlin, 1937).

From the large series of shells available for study, it became apparent that the species is extremely variable; the majority of shells, however, falls within the pattern of *Conus lachrymosus* and *C. rivularius,* and not one shell was found to resemble Reeve's *C. boeticus.*

Two other species, often associated with *Conus boeticus,* are *C. piperatus* Reeve, 1844 (*non* Dillwyn, 1817). later renamed *C. dillwyni* by Reeve in his Emendations (1848, p. 2), and *C. ruppelli* Reeve, 1848. These two are somewhat similar in appearance; however in *C. dillwyni* the interior of the aperture is brown, besides differing in pattern and other features, and *C. ruppelli* has distinct white coronations with brown interstices. I would hesitate to associate these two species with *C. lachrymosus.*

Conus cerinus Reeve, 1848 (Suppl. pl. 3, figs. 283 a, 283 b), and *C. eximius* Reeve, 1849 (Suppl. pl. 6, fig. 256) also resemble *C. lachrymosus*; further study and comparison of Reeve's type specimens could prove them to be identical.

31. *Conus leopardus* (Röding, 1798)
(Plate 12, Figure 1)

1798. *Cucullus leopardus* Röding, Mus. Bolten., p. 41
1822. *Conus millepunctatus* Lamarck, Hist. Nat. Anim. s. Vert., 7: 461 (non *Cucullus millepunctatus* Röding, 1798)
1937. *Conus millepunctatus* var. *aldrovandi* Dautzenberg, Mém. Mus. Roy. Hist. Nat. Belg., 2 (18): 171 (non *C. aldrovandi* Risso, 1826)

Shell: Shell large and heavy. Body whorl cream to ivory, ornamented with transverse rows of blackish-brown, longitudinally oblong spots; base white, truncate and folded. Shoulder rounded, smooth, spire low, blunt, white and flecked with blackish-brown blotches; small specimens have sub-canaliculate whorls. Aperture narrow, interior white.

Periostracum greenish-brown, smooth and very thick.

Egg capsules are large, oval, ridged and white in colour; capsules measured approximately 26 mm in height, 19 mm in maximum width and 6 mm in thickness; they were deposited on the substrate in rows.

Type locality: None. ("Ocean Asiatique," Lamarck, 1822).

H: 40 to 150 mm; W: 56 to 67%; HS: 3 to 9%; AA: 130° to 160°

Habitat: In patches of sand, often exposed, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.
Discussion: The species differs from *Conus litteratus* in being larger, with a slightly different shape and arrangement of the blackish-brown blotches, truncated white base, more rounded shoulder, and lacking the transverse yellow bands and larger squarish blotches at the shoulder.

32. *Conus litoglyphus* Hwass in Bruguière, 1792
(Plate 17, Figure 61)

1792. *Conus litoglyphus* Hwass in Bruguière, Encycl. Méth. Vers, **1**: 692
1798. *Cucullus cinamomeus* Röding, Mus. Bolten., p. 43
1798. *Cucullus cimamomeus* Röding, Mus. Bolten., p. 43
1798. *Cucullus orleanus* Röding, Mus. Bolten., p. 44
1807. *Conus subcapitaneus* Link, Beschr. Nat. Samml. Univ. Rostock, Abt. 3, p. 103
1845. *Conus lacinulatus* Kiener, Spéc. Gén. Icon. Coq. Viv., **2**: 312, pl. 108, fig. 2
1865. *Conus carpenteri* Crosse, Journ. Conchyl., Paris, **13**: 302, pl. 9, fig. 1

Shell: Shell elongate and conical. Body whorl yellowish-brown to chestnut brown, with two white transverse bands at shoulder and center; the central band is either continuous or interrupted, while the shoulder band is composed of irregular white blotches. Base bears 3 to 5 coarse spiral ridges which are sometimes granulose and stained with dark brown. Shoulder angulate, smooth, spire depressed, concave to straight, flecked with brown and white; whorls channeled and axially cancellate. Aperture straight and narrow, stained dark brown near the base, interior white.

Periostracum light brown, transversely ridged and translucent.

Type locality: Mers des grandes Indes.
H: 30 to 42 mm; W: 48 to 56%; HS: 8 to 13%; AA: 115° to 140°
Habitat: Under coral, on sand or reef substrate in deeper water, rarely in shallow water. Rare.
Distribution: West and South Viti Levu. - Indo-West Pacific.
Discussion: Cotton's illustration of *Conus daucus* Hwass in Bruguière (1945, pl. 1, fig. 9) appears to represent *C. litoglyphus* Hwass in Bruguière.

33. *Conus litteratus* Linnaeus, 1758
(Plate 12, Figure 2)

1758. *Conus litteratus* Linnaeus, Syst. Nat., ed. 10, p. 712, no. 252
1798. *Cucullus byssinus* Röding, Mus. Bolten., p. 41
1798. *Cucullus pardus* Röding, Mus. Bolten., p. 41
1840. *Conus brevis* J. de C. Sowerby, Tr. Geol. Soc. London, (2) **5** (2): 329, pl. 26, fig. 33
1844. *Conus gruneri* Reeve, Conch. Icon., **1**, pl. 43, spec. 231

Shell: Shell large, solid. Body whorl cream to ivory, ornamented with transverse rows of blackish-brown, usually rhomboidal spots; occasionally 1 to 3 narrow transverse yellow bands encircle the body whorl. Base pointed, stained with violet-brown. Shoulder distinctly angulate, smooth, with larger squarish, blackish-brown blotches which extend onto the body whorl; spire low, almost flat. Aperture narrow, white within.
Type locality: O. asiatico.
H: 60 to 94 mm; W: 52 to 58%; HS: 5 to 9%; AA: 140° to 165°
Habitat: In patches of sand, in deeper water, rarely collected in shallow water. Moderately rare.
Distribution: Throughout Fiji. - Indo-West Pacific.
Discussion: The species differs from *Conus leopardus* Röding in being generally smaller, having an almost flat spire, angular shoulder, and pointed base stained with violet-brown, and occasionally yellow transverse bands.

34. *Conus lividus* Hwass in Bruguière, 1792
(Plate 16, Figure 50)

1792. *Conus lividus* Hwass in Bruguière, Encycl. Méth. Vers, **1**: 630
1798. *Cucullus monachos* Röding, Mus. Bolten., p. 39
1807. *Conus plebejus* Link, Beschr. Nat. Samml. Univ. Rostock, Abt. 3, p. 106

Shell: Shell solid, conical. Body whorl olive-brown, with two white or bluish-white transverse bands at shoulder and center; body whorl striate, striae granulose basally, obsolete towards the shoulder, base stained with purple. Shoulder angulate, coronate, spire white, slightly elevated, often eroded; whorls obsoletely striate. Aperture narrow,

Explanation of Plate 17

Figure 53: *Conus moluccensis* Küster. Fiji (x 1.25)
Figure 54: *Conus acutangulus* Lamarck. Fiji (x 1.4)
Figure 55: *Conus insculptus* Kiener. Fiji (x 1.5)
Figure 55a: *Conus insculptus* Kiener. Maqueda Bay, Samar, Philippine Islands (x 1.6)
Figure 56: *Conus pertusus* Hwass. Fiji (x 1.7)
Figure 57: *Conus nussatella* Linnaeus. Fiji (x 0.85)
Figure 58: *Conus cylindraceus* Broderip & Sowerby. Fiji (x 1.8)
Figure 59: *Conus mitratus* Hwass. Fiji (x 1.6)
Figure 60: *Conus glans* Hwass. Fiji (x 1.5)
Figure 61: *Conus litoglyphus* Hwass. Fiji (x 1.0)
Figure 62: *Conus dilectus* Gould. Fiji (x 2.8)

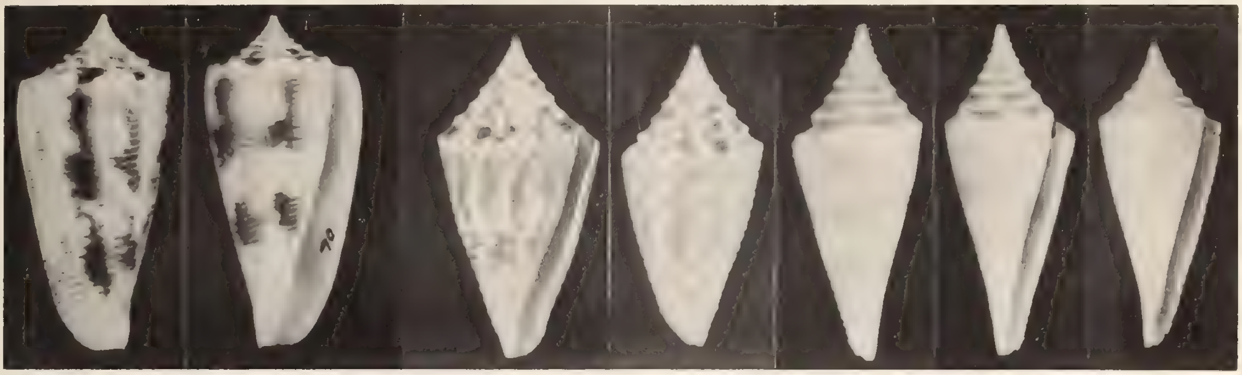

Figure 53 Figure 54 Figure 55

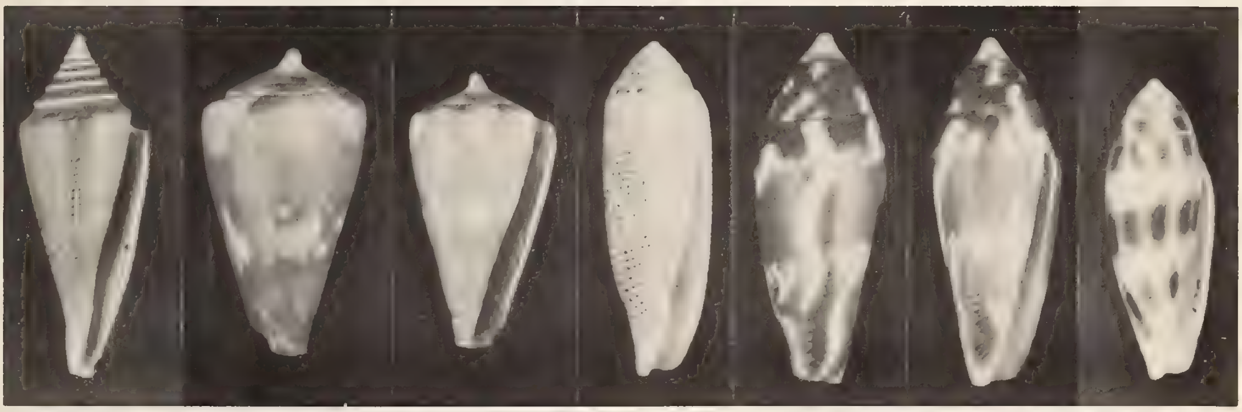

Figure 55 a Figure 56 Figure 57 Figure 58 Figure 59

Figure 60 Figure 61 Figure 62

photo. W. Cernohorsky

interior purple, with a light band near shoulder and one in the center.

Periostracum brown, smooth and thick.

All parts of the animal are black, finely spotted with red.

Type locality: Antilles [error], Îsle de France (Mauritius), Indes orientales.

H: 25 to 60 mm; W: 53 to 59%; HS: 8 to 19%; AA: 105° to 140°

Habitat: Under coral, on reef and sand substrate, and in crevices of coral reef platforms, often exposed at low tide. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: In nature the species feeds on polychaete annelids and enteropneusts (KOHN, 1963).

35. *Conus magus* LINNAEUS, 1758

(Plate 15, Figure 41)

1758. *Conus magus* LINNAEUS, Syst. Nat., ed. 10, p. 716, no. 276
1792. *Conus raphanus* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 722
1798. *Cucullus caesius* RÖDING, Mus. Bolten., p. 48
1822. *Conus carinatus* SWAINSON, Zool. Illust., **2**, pl. 112
1844. *Conus epistomium* REEVE, Conch. Icon. **1**: pl. 42, spec. 227
1844. *Conus ustulatus* REEVE, Conch. Icon., **1**: pl. 44, spec. 239
1845. *Conus striolatus* KIENER, Spéc. Gén. Coq. Viv., **2**: 266, pl. 105, fig. 1
1857.[?] *Conus adansoni* SOWERBY, Thes. Conch. **3**: 38, pl. 199, figs. 286, 287, 288, 289 (non *Conus adansonii* LAMARCK, 1810)
1860. *Conus rollandi* BERNARDI, Journ. Conchyl., Paris, **8**: 332, pl. 12, fig. 4
1864.[?] *Conus consul* BOIVIN, Journ. Conchyl., Paris, **12**: 33, pl. i, figs. 5, 6
1865.[?] *Conus signifer* CROSSE, Journ. Conchyl., Paris, **13**: 308, pl. 10, fig. 6
1866. *Conus tasmaniae* SOWERBY, Thes. Conch., **3**: 328, pl. 27, fig. 636
1866. *Conus borneensis* SOWERBY, Thes. Conch., **3**: 329, pl. 28, fig. 648 (non *Conus borneensis* ADAMS & REEVE, 1848)
1875.[?] *Conus epistomioides* WEINKAUFF, Syst. Conch. Cab., (2), Lief. 233, p. 315, pl. 57, figs. 5, 6
1910. *Conus magus* var. *decurtata* DAUTZENBERG, Journ. Conchyl., Paris, **58**: 26

Shell: Shell elongate. Body whorl white to cream, ornamented with large, irregular green to olive-brown or blackish-brown blotches, usually arranged longitudinally; numerous black and white revolving lines are superimposed on the pattern, which is at times interrupted to form a white central band. The base has a few strong, oblique ridges. Shoulder slightly angulate, at times slightly rounded, smooth, spire depressed or slightly elevated, concave to straight, flecked with dark brown and white; whorls bear three distinct spiral striae. Aperture narrow, widening basally, interior white.

Periostracum light brown, smooth and moderately translucent to opaque in adults, fawn to pale brown, minutely ridged and tufted in juvenile specimens.

Juvenile specimens are pale fawn, with a minimum of brown blotches.

Type locality: None. ("Indian Ocean," HWASS in BRUGUIÈRE, 1792).

H: 16 to 60 mm; W: 46 to 53%; HS: 14 to 18%; AA: 95° to 110°

Habitat: Under coral, on sand substrate, in shallow water; juveniles are found buried in sandy patches. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: Dr. Kohn (personal communication) found the radular teeth of Fijian specimens of *Conus magus* to be proportionately longer in relation to shell length (1:10), than those from the Philippines and Eniwetok (1:13 to 1:15).

This is an extremely variable species, which will vary in colour and pattern from region to region; even within the Fiji Islands various colour forms are found. An extensive synonymy for this species can be found in DAUTZENBERG, 1937.

36. *Conus marmoreus* LINNAEUS, 1758

(Plate 12, Figure 9)

1758. *Conus marmoreus* LINNAEUS, Syst. Nat., ed. 10, p. 712, no. 250
1798. *Cucullus equestris* RÖDING, Mus. Bolten., p. 38 (non *C. equestris* RÖDING, 1798, p. 46)
1798. *Cucullus proarchithalassus* RÖDING, Mus. Bolten., p. 38
1798. *Cucullus torquatus* RÖDING, Mus. Bolten., p. 38 (non *C. torquatus* RÖDING, 1798, p. 45)
1811. *Conus maculatus* PERRY, Conchology, pl. 24, fig. 4
1859. *Conus nigrescens* SOWERBY, Proc. Zool. Soc. London, pt. **27**: 429, pl. 49, fig. 2
1875. *Conus pseudomarmoreus* CROSSE, Journ. Conchyl., Paris, **23**: 223, pl. 9, fig. 4

Shell: Shell conical, solid, heavy. Body whorl blackish, ornamented with ivory-white, trigonal blotches of varying sizes from base to shoulder. Shoulder angulate, coronate, spire depressed, alternately flecked with black and white; whorls canaliculate, smooth. Aperture narrow, slightly wider basally, interior pinkish-white.

Periostracum smooth, thin, translucent orange.

Juvenile specimens have pronounced transverse ridges on the body whorl.
Type locality: Asia.
H: 30 to 102 mm; W: 53 to 59%; HS: 4 to 13%; AA: 125° to 150°
Habitat: Under coral, on sand substrate and among weed, in shallow water. Common.
Distribution: Throughout Fiji. - Indo-West Pacific.
Discussion: Semi-albino and albino specimens of *Conus marmoreus* have been recorded from Bourail, New Caledonia. The frequent occurrence of albinotic specimens in this particular population points to genedrift as a possible cause. Albinotic or melanistic specimens of *C. marmoreus* have not been recorded from Fiji waters.

The species has been observed to be molluscivorous in nature, and in all probability has a venomous sting harmful to vertebrates.

37. *Conus miles* Linnaeus, 1758
(Plate 12, Figure 7)

1758. *Conus miles* Linnaeus, Syst. Nat., ed. 10, p. 713, no. 255

Shell: Shell solid, broad. Body whorl white, ornamented with orange to orange-brown, longitudinal wavy lines, and one narrow dark brown transverse band below the shoulder and another, broader band at the base; base bears widely spaced spiral ridges. Shoulder angulate, smooth, spire moderately elevated, concave or straight, white and axially lined with orange brown lines; whorls obsoletely striate. Aperture narrow, lip thin, interior violet, with a light band at shoulder and another above the base.

Periostracum greenish-brown, thick, ridged, tufted.
Type locality: India.
H: 26 to 76 mm; W: 56 to 67%; HS: 11 to 16%; AA: 105° to 125°
Habitat: Under coral, on reef substrate, in shallow water. Common.
Distribution: West, South and East Viti Levu. - Indo-West Pacific.
Discussion: Egg capsules are small, ridged and white in colour; capsules measured approximately 9.5 mm in height and 6.0 mm in maximum width; they were laid on the substrate in parallel rows.

Kohn (1959) recorded Hawaiian specimens of *Conus miles* as obsoletely coronate at the shoulder; this is not the case in Fiji specimens.

38. *Conus miliaris* Hwass in Bruguière, 1792
(Plate 18, Figure 72)

1792. *Conus miliaris* Hwass in Bruguière, Encycl. Méth. Vers, 1: 629

Shell: Shell small, solid. Body whorl rose-pink, ornamented with two interrupted transverse bands, composed of irregular white blotches; numerous interrupted orange-brown lines revolve around the body whorl. Transverse granulose ridges extend from the base halfway towards the shoulder. Shoulder angulate, coronations white and distinct, interspaces with short orange-brown streaks; spire low or slightly elevated, white and coronate. Whorls bear two distinct spiral ridges. Aperture narrow, slightly widening basally, interior orange-brown, with a white median band.

Periostracum thin, smooth, translucent orange.
Type locality: China.
H: 15 to 36 mm; W: 61 to 70%; HS: 7 to 15%; AA: 120° to 145°
Habitat: Under coral, on sand substrate and sand pockets of coral reefs in shallow water. Uncommon.
Distribution: West, South and East Viti Levu. - Indo-West Pacific.

39. *Conus mitratus* Hwass in Bruguière, 1792
(Plate 17, Figure 59)

1792. *Conus mitratus* Hwass in Bruguière, Encycl. Méth. Vers, 1: 738
1870. *Conus mitraeformis* Sowerby, Proc. Zool. Soc. London, p. 256

Shell: Shell small, elongate-cylindrical. Body whorl cream, ornamented with orange-brown rectangular blotches arranged to form three interrupted transverse bands at the base, center and shoulder; distinct small granules are placed transversely on the body whorl, and extend from

Explanation of Plate 18

Figure 63: Type figure of *Conus eximius* Reeve, 1849
Figure 64: Type figure of *Conus lachrymosus* Reeve, 1849
Figure 65: Type figure of *Conus rivularius* Reeve, 1849 (figures 63, 64 and 65 x 1.4)
Figure 66: *Conus lachrymosus* Reeve. Fiji (x 1.85)
Figure 66a: *Conus lachrymosus* Reeve, almost white, sparsely ornamented specimen. Fiji (x 1.7)
Figure 66b: *Conus lachrymosus* Reeve. Fiji (x 1.85)
Figure 66c: *Conus lachrymosus* Reeve. juvenile. Fiji (x 2)
Figure 66d: enlarged view of *Conus lachrymosus* Reeve, showing degree of nodulosity of shoulder and spire (approximately x 3.0)
Figure 67: *Conus aristophanes* Sowerby. Fiji (x 1.35)
Figure 68: *Conus coronatus* Gmelin. Fiji (x 1.0)
Figure 69: *Conus ebraeus* Linnaeus. Fiji (x 0.9)
Figure 70: *Conus chaldaeus* (Röding). Fiji (x 1.0)
Figure 71: *Conus sponsalis* Hwass. Fiji (x 1.1)
Figure 72: *Conus miliaris* Hwass. Fiji (x 1.0)
Figure 73: *Conus musicus* Hwass. Fiji (x 1.3)
Figure 74: *Conus rattus* Hwass. Fiji (x 0.7)

Figure 63 Figure 64 Figure 65 Figure 66 Figure 66 a

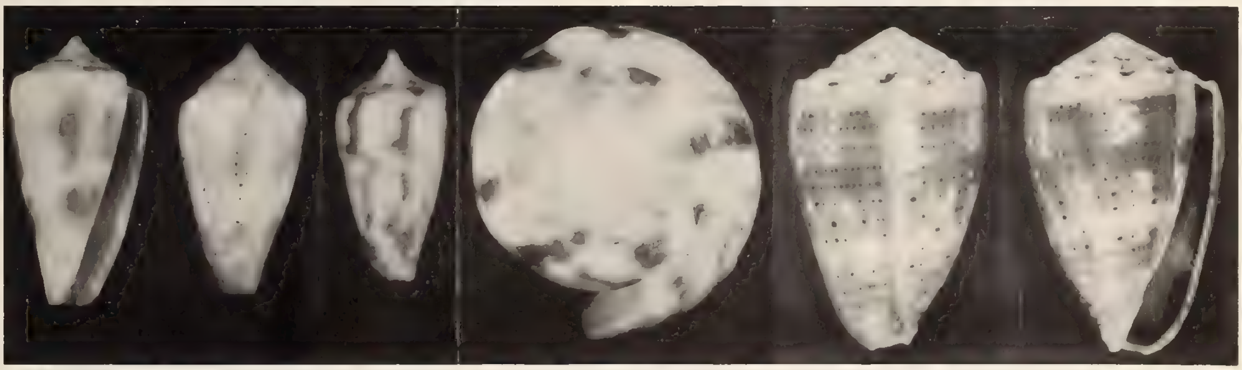

Figure 66 b Figure 66 c Figure 66 d Figure 67

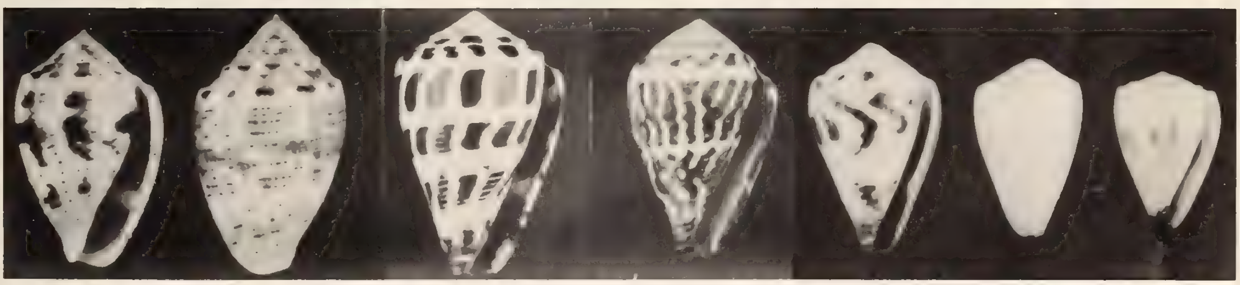

Figure 68 Figure 69 Figure 70 Figure 71

Figure 72 Figure 73 Figure 74

photo. W. Cernohorsky

base to shoulder. Shoulder indistinct, spire extremely high, convex, flecked with orange-brown; whorls striate. Aperture very narrow, slightly widening basally, interior white.
Type locality: Indian Ocean.
H: 18 to 33 mm; W: 36 to 43%; HS: 21 to 29%; AA: 60° to 80°
Habitat: Under coral, on sand and reef substrate, in deeper water; rarely collected in shallow water. Rare.
Distribution: West and South Viti Levu. - Indo-West Pacific.

40. *Conus moluccensis* Küster, 1838
(Plate 17, Figure 53)

1838. *Conus moluccensis* Küster, Syst. Conch. Cab., (2), Lief. 8, p. 121, pl. 23, figs. 4, 5
1843. *Conus stainforthi* Reeve, Conch. Icon., **1**: pl. 1, spec. 1
1854. *Conus pulcher* A. Adams, Proc. Zool. Soc. London, p. 117 (non *Conus pulcher* Solander, 1786)
1859. *Conus proximus* Sowerby, Proc. Zool. Soc. London, p. 429, pl. 49, fig. 1

Shell: Shell small, thin. Body whorl whitish to pale fawn, ornamented with dark brown longitudinal streaks and blotches, usually interrupted centrally to form a light transverse zone; numerous fine brown interrupted transverse lines encircle the body whorl. Base distinctly ridged, ridges becoming flat and broad towards the shoulder; base distinctly concave and folded. Shoulder angulate, coronate, interspaces stained with brown, spire depressed, coronate and concave; apex elevated and mammillate, whorls striate. Aperture narrow at shoulder, widening basally, interior whitish.

Periostracum light brown, smooth, thin, translucent.
Type locality: Moluccas.
H: 18 to 36 mm; W: 45 to 51%; HS: 12 to 17%; AA: 90° to 110°
Habitat: Buried in sand patches, shallow and deeper water. Rare.
Distribution: West Viti Levu and Mamanuca group. - New Caledonia, Moluccas.

41. *Conus moreleti* Crosse, 1858
(Plate 16, Figure 52)

1843. *Conus elongatus* Reeve, Conch. Icon., **1**, pl. 27, fig. 157 (non *Conus elongatus* Borson, 1820)
1849. *Conus oblitus* Reeve, Conch. Icon., Emend., pl. 1 (non *Conus oblitus* Michelotti, 1847)
1858. *Conus moreleti* Crosse, Rev. Mag. Zool., ser. 2, **10**: 122 (nom. nov. pro *Conus elongatus* Reeve, 1843)

Shell: Shell elongate. Body whorl orange-brown to olive-brown, ornamented with faint, lighter coloured narrow transverse bands at the shoulder and center; base stained with purplish-brown, spiral striae granulose. Shoulder angulate, coronate, spire very low, convex and coronate; whorls striate. Aperture narrow, parallel to body whorl, interior purple with an orange marginal edge.

Periostracum thin, translucent orange-brown, minutely tufted.
Type locality: None.
H: 17 to 43 mm; W: 47 to 53%; HS: 4 to 12%; AA: 115° to 150°
Habitat: Under coral, on reef substrate, in deeper water. Rare.
Distribution: North and West Viti Levu. - Indo-West Pacific.

42. *Conus musicus* Hwass in Bruguière, 1792
(Plate 18, Figure 73)

1792. *Conus musicus* Hwass in Bruguière, Encycl. Méth. Vers, **1**: 629
1849.[?] *Conus mighelsi* Kiener, Spéc. Gén. Icon. Coq. Viv., **2**: 352, pl. 103, fig. 1

Shell: Shell small. Body whorl white or bluish-white, ornamented with blackish-brown transverse dashes and dots, and granulose ridges, which become obsolete towards the shoulder; base stained with purple. Shoulder angulate, coronate, interspaces stained with black, spire low or slightly elevated, nodulose, flecked with black. Aperture narrow, interior purplish-brown.

Periostracum light brown, smooth, thin, translucent.
Type locality: China.
H: 10 to 29 mm; W: 60 to 66%; HS: 12 to 16%; AA: 110° to 130°
Habitat: In crevices of coral reefs, usually at reef's edge, in shallow water. Uncommon.
Distribution: West and South Viti Levu. - Indo-West Pacific.

43. *Conus mustelinus* Hwass in Bruguière, 1792
(Plate 14, Figure 31)

1792. *Conus mustelinus* Hwass in Bruguière, Encycl. Méth. Vers, **1**: 654
1860.[?] *Conus henoquei* Bernardi, Journ. Conchyl., **8**: 380, pl. 13, fig. 4

Shell: This species differs from *Conus capitaneus* Linnaeus by being more elongate and slender, especially at the shoulder; the white central band is placed obliquely on the body whorl and is bordered by two rows of blackish round spots, not perpendicular blotches as in *C. capitaneus*.

Periostracum dark brown, coarse, moderately thick.
Type locality: Indian Ocean.

H: 20 to 82 mm; W: 54 to 59%; HS: 8 to 15%; AA: 110° to 140°

Habitat: In crevices and under coral, on sand or reef substrate, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: DODGE (1953) regards the species as synonymous with *Conus capitaneus* LINNAEUS. Both species are clearly separable on conchological features alone; statistical measurements taken from large series of both species indicate that as far as the width is concerned, *C. mustelinus* does not even attain the lowest width index as recorded for the narrowest specimen of *C. capitaneus*. Kohn (personal communication) found the radular teeth of Fiji specimens of *C. mustelinus* to be similar to those of *C. capitaneus*, but nevertheless separable.

44. *Conus nussatella* LINNAEUS, 1758
(Plate 17, Figure 57)

1758. *Conus nussatella* LINNAEUS, Syst. Nat., ed. 10, p. 716, no. 273

1782. *Conus mussatellana* LINNAEUS, SCHRÖTER, Mus. Gottwald, p. 23, pl. 13, figs. 96 a, 96 b, 96 c, pl. 43, fig. 52 a

1834. *Conus nussatella* var. *tenuis* SOWERBY, Conch. Ill., pt. 54, fig. 62

1877. *Hermes nussatellata* (LINNAEUS), BRAZIER, Proc. Linn. Soc. N.S.W., **1**: 291

Shell: Shell elongate, cylindrical. Body whorl white or cream, longitudinally blotched and streaked with reddish-brown, and transversely dotted with orange-brown spots; last whorl spirally striate, striae closely set, distinctly granulose. Shoulder indistinct, spire elevated, convex, dotted with orange-brown. Aperture narrow, slightly widening basally, interior white.

Periostracum yellowish-brown, smooth, thin, translucent.

Type locality: Nussatello Insulam Asiae.

H: 30 to 65 mm; W: 32 to 38%; HS: 13 to 16%; AA: 75° to 100°

Habitat: Under coral, on reef substrate, in shallow and deeper water. Rare.

Distribution: Throughout Fiji. - Indo-West Pacific.

45. *Conus obscurus* SOWERBY, 1833
(Plate 15, Figure 40)

1833. *Conus obscurus* SOWERBY, Conch. Illust., pt. 29, p. 2, fig. 26

1943. *Conus halitropus* BARTSCH & REHDER, Proc. Biol. Soc. Wash., **56**: 88

Shell: Shell small, fragile. Body whorl pale violet, ornamented with irregular brown blotches and faint transverse lines of brown and white dots; base transversely striate. Shoulder rounded, smooth, spire low to moderately elevated, apex high; whorls striate, cancellate. Aperture wide, flaring basally, interior violet.

Periostracum thin, smooth, translucent yellow.

Type locality: Arabia.

H: 15 to 41 mm; W: 39 to 45%; HS: 9 to 18%; AA: 85° to 105°

Habitat: Under coral, on reef substrate, in deeper water. Rare.

Distribution: West and South Viti Levu. - Pacific (Indian Ocean?).

Discussion: KOHN (1963) reported the species to be piscivorous in nature; he recorded five cases of *Conus obscurus* stings, which did not prove fatal to the victims.

46. *Conus omaria* HWASS in BRUGUIÈRE, 1792
(Plate 13, Figure 19)

1792. *Conus omaria* HWASS in BRUGUIÈRE, Encyclop. Méth. Vers, **1**: 743

1792. *Conus rubiginosus* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 746

1843.[?] *Conus magnificus* REEVE, Conch. Icon., **1**, pl. 6, spec. 32

Shell: Shell elongate-ovate. Body whorl dark reddish-brown, ornamented with trigonal, irregular white blotches, usually arranged to form two transverse and two longitudinal bands; striae pronounced at the base, becoming obsolete towards the shoulder. Shoulder slightly angulate, shoulder whorl channelled, spire depressed to slightly elevated, concave, marked with white trigonal blotches; whorls striate. Aperture wide, nearly perpendicular, flaring basally, interior rosy-white.

Periostracum thin, smooth, translucent orange.

Juvenile specimens, only 20 mm in height, already display the full markings of the adults.

Type locality: Ocean Asiatique, Madagascar, Manille.

H: 18 to 75 mm; W: 43 to 48%; HS: 9 to 11%; AA: 100° to 125°

Habitat: Buried in sand under coral boulders, in shallow and deeper water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: Egg capsules are oval, ridged, greyish-brown in colour; capsules measured approximately 16 mm in height and 7 mm in maximum width; they were deposited on the substrate in a cluster. This species is capable of inflicting a venomous bite that may prove fatal to humans.

Some writers synonymized *Conus omaria* with *C. pennaceus* BORN, 1778. Apart from the colour pattern, *C. pennaceus* is somewhat pyriform, more rounded and broader at the shoulder. Two specimens of *C. pennaceus* recorded by KOHN (1959) from Hawaii and the Maldive Islands had a width index of 55% and 58% respectively; both these specimens exceed the broadest *C. omaria* recorded from Fiji.

47. *Conus pertusus* HWASS in BRUGUIÈRE, 1792
(Plate 17, Figure 56)

1792. *Conus pertusus* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 686
1798.[?] *Cucullus antillarum* RÖDING, Mus. Bolten., p. 47
1810. *Conus amabilis* LAMARCK, Ann. Mus. Hist. Nat. Paris, **15**: 425
1817. *Conus festivus* DILLWYN, Descr. Cat. Rec. Shells, **1**: 413

Shell: Shell small, fragile. Body whorl orange-red, ornamented with two interrupted transverse bands, composed of whitish blotches at the shoulder and center; distant punctured spiral lines encircle the shell, but are often obsolete. Shoulder rounded, at times slightly angulate, smooth, spire low, concave, alternately flecked with orange-red and white, apex pointed; whorls striate. Aperture narrow, interior pink.
Type locality: Grandes Indes.
H: 15 to 31 mm; W: 50 to 57%; HS: 10 to 18%; AA: 100° to 125°
Habitat: Under coral heads, usually in deeper water. Very rare.
Distribution: West and South Viti Levu. - Pacific.

48. *Conus planorbis* BORN, 1780
(Plate 14, Figures 29, 29 a)

1780. *Conus planorbis* BORN, Test. Mus. Caes. Vindob., p. 164, pl. 7, figs. 13, 14
1791. *Conus polyzonias* GMELIN, Syst. Nat., ed 13, p. 3392
1792. *Conus vulpinus* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 648

Shell: Shell conical, moderately solid. Body whorl yellow to fulvous, ornamented with two broad brown transverse bands that may be sharply defined, indistinct and merging, or lacking altogether; continuous or interrupted brown lines encircle the body whorl and are occasionally absent. Base distinctly striate, striae granulose, usually obsolete towards the shoulder; base stained with purplish-brown or dark brown. Shoulder angulate, smooth, spire low to moderately elevated, concave to straight, maculated with dark brown; whorls slightly channelled, with 4 to 5 spiral striae per whorl. Aperture narrow, widening basally, interior white.

Periostracum brown, moderately thick, transversely ridged and tufted.
Type locality: None.
H: 16 to 60 mm; W: 54 to 59%; HS: 7 to 15%; AA: 110° to 145°
Habitat: In sand patches, or under coral on sand substrate, in shallow water. Uncommon.
Distribution: Throughout Fiji. - Indo-West Pacific.
Discussion: A very variable species, especially in the colour patern, granulosity of spiral striae and height of spire. A specimen collected by A. Jennings (personal communication) in Fiji was of a plain yellow colour, and granulose from base to shoulder.

49. *Conus pulicarius* HWASS in BRUGUIÈRE, 1792
(Plate 14, Figure 28)

1792. *Conus pulicarius* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 622
1792. *Conus fustigatus* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 623
1798. *Cucullus punctulatus* RÖDING, Mus. Bolten., p. 40
1845. *Conus vautieri* KIENER, Spéc. Gén. Icon. Coq. Viv., **2**: 350, pl. 100, fig. 3

Shell: Shell solid, slightly ventricose. Body whorl white, ornamented with round blackish spots, often arranged in transverse bands or densely grouped together; base transversely ridged. Shoulder angulate, coronate, coronations occasionally obsolete, spire low, whitish, faintly spotted with black; apex pointed, whorls striate. Aperture narrow, slightly widening basally, interior white, often with a faint rose or pale brown tinge.

Periostracum thick, smooth, orange-brown.

Juvenile specimens 12 mm in height are translucent in appearance and bear the completed pattern and coronations of the adult; the periostracum is very thin and translucent fawn.
Type locality: Pacific Ocean.
H: 10 to 61 mm; W: 55 to 66%; HS: 8 to 16%; AA: 110° to 145°
Habitat: Buried in sand patches, in shallow water. Common.
Distribution: Throughout Fiji. - Indo-West Pacific.
Discussion: A specimen collected by the author in Fiji is smooth at the shoulder and spire, and only faint nodules are visible on the early whorls.

This species feeds on polychaete annelids and echiuroids in nature (KOHN, 1963).

50. *Conus quercinus* SOLANDER in LIGHTFOOT, 1786
(Plate 13, Figure 15)

1786. *Conus quercinus* SOLANDER in LIGHTFOOT, Cat. Portland Mus., p. 67, no. 1501
1791. *Conus cingulum* GMELIN, Syst. Nat., ed. 13, p. 3378
1858. *Conus ponderosus* SOWERBY, Thes. Conch., Index, **3**: 54 (non *C. ponderosus* BROCCHI, 1814; non *C. ponderosus* GRATELOUP, 1835)

Shell: Shell solid, broad. Body whorl yellow, ornamented with closely set transverse brown lines, which may occasionally be absent; base folded, spirally striate, striae

becoming obsolete towards the shoulder. Shoulder slightly rounded, smooth, spire depressed, concave; apex high, whorls striate. Aperture wide, parallel to body whorl, interior white; basal end of aperture and fold tinged pinkish green.

Periostracum thick, smooth, dark greenish-brown.

Juvenile specimens are somewhat slender in shape, glossy, with pronounced brown revolving lines.

Type locality: None.

H: 28 to 104 mm; W: 58 to 68%; HS: 5 to 10%; AA: 125° to 150°

Habitat: Buried in sand, among weed, occasionally on sand substrate under coral boulders. Common in the South, rare in North Viti Levu.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: This species feeds on enteropneusts and polychaete annelids (Kohn, 1963).

51. *Conus radiatus* Gmelin, 1791
(Plate 12, Figure 6)

1791. *Conus radiatus* Gmelin, Syst. Nat., ed. 13, p. 3386
1844. *Conus martinianus* Reeve, Conch. Icon., 1, pl. 40, spec. 217

Shell: Shell elongate, fairly light. Body whorl brown to blackish-brown, ornamented with deep, axially cancellate, transverse grooves, separated by flat interspaces, and extending about halfway towards the shoulder; under magnification transverse punctate striae are discernible on the remainder of the body whorl. Shoulder slightly angulate, smooth, spire depressed, concave, pale brown with a few darker streaks; apex raised, dark brown, whorls channelled, with 3 to 4 striae per whorl. Aperture narrow, widening basally, interior white or pale orange; lip thin, base with a distinct white fold.

Periostracum dark brown, thin and smooth.

Type locality: None (mentioned from Luzon, Philippines, by Reeve).

H: 40 to 70 mm; W: 44 to 49%; HS: 8 to 12%; AA: 110° to 130°

Habitat: In muddy sand, usually in deeper water. Rare.

Distribution: West and South Viti Levu. - Pacific.

52. *Conus rattus* Hwass in Bruguière, 1792
(Plate 18, Figure 74)

1792. *Conus rattus* Hwass in Bruguière, Encycl. Méth. Vers, 1: 700
1792. *Conus taitensis* Hwass in Bruguière, Encycl. Méth. Vers, 1: 713
1843. *Conus taheitensis* Hwass, Reeve, Conch. Icon., 1, pl. 15, spec. 78
1857. *Conus viridis* Sowerby, Thes. Conch., 3: 20, pl. 5, fig. 102

Shell: Shell small, conical. Body whorl brown to dark violet-brown, ornamented with two bluish-white transverse bands at the shoulder and center; these transverse bands are composed of whitish blotches and the central band is often obscured by the dark brown base colour of the body whorl. The area below the transverse bands is spotted with small white dots; base spirally striate, less so towards the shoulder. Shoulder angulate, smooth, spire low to slightly elevated, flecked with brown and white, whorls striate. Aperture narrow, lip thin, interior purple.

Periostracum yellowish-brown, slightly opaque, transversely finely ridged.

Type locality: Mers d'Amerique [error].

H: 13 to 52 mm; W: 55 to 66%; HS: 8 to 15%; AA: 110° to 140°

Habitat: Under coral boulders, on sand substrate, and in crevices of coral reefs, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: Egg capsules are small and oval, ridged, and grey in colour; they were deposited on the substrate in rows.

53. *Conus retifer* Menke, 1829
(Plate 13, Figure 25)

1829. *Conus retifer* Menke, Verz. Anz. Conch.-Samml. Malsburg, p. 68
1834. *Conus textile* var. *sulcata* Sowerby, Conch. Illust., pt. 56/57, p. 3, fig. 76 (non *C. sulcatus* Hwass in Bruguière, 1792)
1834. *Conus solidus* Sowerby, Conch. Illust., (large list), p. 57 (non *C. solidus* Gmelin, 1791)

Shell: Shell pyriform, solid. Body whorl dark reddish-brown, ornamented with irregularly sized trigonal spots, usually arranged to form two transverse bands on body whorl; area between the white markings bears dark orange and brown longitudinal lines; body whorl transversely striate. Shoulder well rounded, smooth, spire high, flecked with white and brown; whorls striate. Aperture wide, interior white.

Periostracum thin, smooth, translucent yellow.

Type locality: None.

H: 34 to 57 mm; W: 52 to 61%; HS: 19 to 26%; AA: 90° to 110°

Habitat: Under coral, on sand substrate, in deeper water. Very rare.

Distribution: South-West and South Viti Levu. - Pacific.

54. *Conus sanguinolentus* Quoy & Gaimard, 1834
(Plate 16, Figures 51, 51 a, 51 b)

1834. *Conus sanguinolentus* Quoy & Gaimard, Voyage Astrolabe, Zool. 3: 99, pl. 53, fig. 18

Shell: Shell conical, fairly solid. Body whorl uniformly

olive-brown to dark brown, lower half of body whorl spirally striate, often granulose, base stained with purple; the majority of shells examined lacked the narrow central transverse band which characterizes *Conus lividus;* only a few specimens bore an extremely pale brown central band. Shoulder angulate, coronations distinct and elevated, whitish in colour, with interspaces stained with yellowish-brown; spire depressed, coronations white, with remaining area brownish-yellow. Whorls spirally striate. Aperture narrow, interior purplish, lacking the distinct bluish-white median band.

Periostracum brown, smooth, moderately thick.

The animal is a vivid red, finely spotted with dark red.

Type locality: New Guinea.

H: 20 to 52 mm; W: 55 to 64%; HS: 5 to 13%; AA: 110° to 155°

Habitat: Under coral boulders, on sand and reef substrate, in shallow water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: This species has almost always been associated with *Conus lividus* Hwass in Bruguière; it differs from the latter species in the absence of the whitish transverse bands, the pronounced, differently sculptured coronations, the peculiarly coloured spire and interspaces, and the uniformly purple coloured aperture.

Quoy & Gaimard (1834) noted that their species closely resembles *Conus lividus* Hwass in Bruguière, especially Lamarck's variation "c," but differed from that species in having a blood-red animal finely speckled with red dots.

Fiji specimens of *Conus sanguinolentus* can be easily separated from those of *C. lividus,* which has an almost blackish animal; the same difference in the colour of live animals has been observed in Kenya by Rawlings (W. R. Barker, personal communication).

In addition to the specimens of *Conus sanguinolentus* collected in Fiji, other reliable records are from Cook Islands (coll. Coppell), the Philippine Islands (coll. W. R. Barker), Mauritius (coll. Rouillard), and Kenya (coll. Rawlings).

55. *Conus scabriusculus* Dillwyn, 1817
(Plate 15, Figure 36)

1817. *Conus scabriusculus* Dillwyn, Descr. Cat. Rec. Shells, **1:** 406

1833. *Conus fabula* Sowerby, Conch. Illust., pt. 24, figs. 5, 5*

Shell: Shell solid, conically-ovate. Body whorl white to pale violet, ornamented with irregular dark brown blotches, often fused together to form larger dark brown patches; closely set elevated granules encircle the body whorl from base to shoulder; tip of base stained with violet. Shoulder rounded, smooth, spire high, plain bluish-white, occasionally flecked with dark brown; spire convex, apex raised, whorls finely striate. Aperture narrow, slightly widening basally, interior of aperture violet with a white marginal edge.

Periostracum yellowish-brown, moderately translucent, ridged and finely tufted.

Type locality: Coast of Guinea.

H: 20 to 58 mm; W: 53 to 58%; HS: 14 to 21%; AA: 85° to 110°

Habitat: In and under coral, on sand substrate, in shallow water. Rare.

Distribution: Throughout Fiji. - Pacific.

Discussion: The size and density of the brown blotches are rather variable; occasional specimens are uniformly dark brown and the white blotches are visible in the form of an interrupted central band, and on the spire.

56. *Conus spectrum* Linnaeus, 1758
(Plate 15, Figure 39)

1758. *Conus spectrum* Linnaeus, Syst. Nat., ed. 10, p. 717, no. 280

1798. *Cucullus carota* Röding, Mus. Bolten., p. 47

1807.[?] *Conus felinus* Link, Beschr. Nat. Samml. Univ. Rostock, Abt. 3, p. 104

1844. *Conus broderipii* Reeve, Conch. Icon., **1**, pl. 46, spec. 254

1844.[?] *Conus conspersus* Reeve, Conch. Icon., **1**, pl. 47, spec. 261

1849. *Conus stillatus* Reeve, Conch. Icon., Suppl., pl. 5, spec. 247

Shell: Shell thin, ventricose. Body whorl white to ivory, ornamented with yellow to yellow-brown irregular blotches, often arranged in longitudinal zones; body whorl transversely striate, striae pronounced at the base, becoming finer and more closely set towards the shoulder. Shoulder angulate, smooth, spire depressed, concave, white with yellowish-brown maculations; apex acute, each whorl bears two distinct spiral striae. Aperture wide, lip thin, ventricose, interior of aperture white.

Periostracum thin, smooth, translucent yellow.

Type locality: Asia.

H: 35 to 45 mm; W: 48 to 54%; HS: 6 to 12%; AA: 110° to 130°

Habitat: Under coral, on sand substrate, in deeper water. Very rare.

Distribution: North and South Viti Levu. - Indo-West Pacific.

Discussion: Linnaeus' specific name "*spectru*" of the 10th edition of his "Systema Naturae" had been emended to "*spectrum*" in the "Museum Ulricae" (1764, p. 562).

57. *Conus sponsalis* HWASS in BRUGUIÈRE, 1792
(Plate 18, Figure 71)

1792. *Conus sponsalis* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 635
1792. *Conus ceylanensis* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 636
1833. *Conus nanus* SOWERBY, Conch. Illust., pt. 24, p. 1, fig. 6

Shell: Shell small, pyriform. Body whorl bluish-white, somewhat whiter near the shoulder, ornamented with either reddish-brown to dark brown wavy longitudinal flammules, or transverse rows of brown dashes, and occasionally with brown longitudinal streaks; individual specimens are plain bluish-white, lacking the markings on the body whorl. Body whorl obsoletely striate, striae pronounced near the base; base stained with dark purplish-brown. Shoulder angulate to slightly rounded, coronate, coronations often obsolete in large adults; spire low, concave to straight, often eroded. Aperture narrow, sides parallel, interior purple, interrupted by two light bands.

Periostracum thin, smooth, translucent fawn.

Juvenile specimens are prominently coronate on shoulder and spire; the transverse spiral striae on the body whorl are distinctly granulose and extend further towards the shoulder than in large adults.

Type locality: Île St. George.

H: 10 to 26 mm; W: 62 to 70%; HS: 8 to 15%; AA: 105° to 140°

Habitat: In crevices of dead and live coral, usually near the reef's edge, in shallow water. Common.

Distribution: West, South and East Viti Levu. - Indo-West Pacific.

Discussion: This species is extremely variable. *Conus ceylanensis* and *C. nanus* appear to be individual variants only, as they are represented in almost every population of *C. sponsalis* in Fiji.

This species feeds on polychaete annelids in nature (KOHN, 1963).

58. *Conus striatellus* LINK, 1807
(Plate 14, Figure 34)

1792. *Conus lineatus* HWASS in BRUGUIÈRE, Encycl. Méth. Vers, **1**: 645 (non *C. lineatus* SOLANDER, 1766)
1807. *Conus striatellus* LINK, Beschr. Nat. Samml. Univ. Rostock, Abt. 3, p. 103
1921. *Conus pulchrelineatus* HOPWOOD, Journ. Conch., **16**: 151 (nom. nov. pro *C. lineatus* HWASS, 1792)

Shell: Shell conical. Body whorl reddish-brown, ornamented with irregular white blotches, forming two interrupted transverse bands at the shoulder and center; the white blotches at the shoulder are usually larger and more widely spaced. The body whorl is encircled by closely set, fine dark brown lines, extending from base to shoulder; base faintly pinkish-brown, transversely striate, striae granulose, becoming obsolete towards the shoulder. Shoulder angulate, smooth, spire elevated, concave to straight, white and maculated with axially curved brown streaks; whorls faintly canaliculate, each whorl with 4 spiral striae. Aperture narrow at shoulder, widening basally, interior white or bluish-white.

Type locality: None ("Indian Ocean," HWASS in BRUGUIÈRE, 1792).

H: 30 to 50 mm; W: 50 to 56%; HS: 9 to 13%; AA: 105° to 125°

Habitat: Under dead coral, on sand substrate, in shallow water. Very rare.

Distribution:: West Viti Levu. - Indo-West Pacific.

59. *Conus striatus* LINNAEUS, 1758
(Plate 12, Figure 12)

1758. *Conus striatus* LINNAEUS, Syst. Nat., ed. 10, p. 716, no. 277
1858. *Conus floridus* SOWERBY, Thes. Conch., **3**: 47, frontispiece, fig. 558

Shell: This species displays a considerable variation of colour pattern; on some specimens the purplish-brown blotches cover the greater part of the body whorl, while other specimens are almost creamy-white with only a few isolated blotches. Fiji specimens have a high, canaliculate spire in contrast to the almost flat, concave spire of Hawaiian specimens.

Periostracum thin, smooth, translucent fawn.

Egg capsules are large, oval, smooth, white in colour; capsules measured approximately 25 to 26 mm in height, 16 mm in maximum width, and 0.8 mm in thickness. Capsules were deposited on the substrate in parallel rows.

Type locality: Hitoe (Amboina).

H: 25 to 102 mm; W: 44 to 50%; HS: 10 to 14%; AA: 105° to 125°

Habitat: Under coral boulders, on sand substrate in shallow water. Juvenile specimens often dredged in sand patches. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: This species is reported to be piscivorous (R. ENDEAN, 1962), but has been observed in Fiji preying on other *Conus* species. *Conus striatus* is believed capable of inflicting a venomous sting, although no fatalities have been reported.

The pale shells of *Conus striatus*, which have a minimum of brown ornamentation on the body whorl, appear

to be ecological variants, as their occurrence is restricted to certain Fijian localities (Manava Island, North Viti Levu, Cuvu Beach, South-west Viti Levu).

60. *Conus sugillatus* Reeve, 1844
(Plate 16, Figure 46)

1844. *Conus sugillatus* Reeve, Conch. Icon., 1, pl. 45, spec. 247

1848. *Conus floridulus* A. Adams & Reeve, Zool. Voy. Samarang, Moll., pt. 1, p. 18, pl. 5, figs. 9 a, 9 b.

Shell: Shell solid, conical. Body whorl brown to violet-brown, ornamented with two white transverse bands at shoulder and center, and transverse, almost continuous, fine brown lines encircle the body whorl; the brown area below the light central band is a darker shade of brown than the one above it. Base spirally ridged, stained with violet. Shoulder angulate, obsoletely nodulose, spire low, concave, purplish, irregularly stained with closely set curved brown streaks; whorls spirally striate, striae intersected by compressed curved axial striae. Aperture narrow, slightly widening anteriorly, interior purple, becoming darker towards the base; purple interior interrupted by two light bands near shoulder and center.

Periostracum light brown, smooth, thin, translucent.

Juvenile specimens have a broader white central band, narrower brown zones, more distinct brown transverse lines and small areas of violet-grey on the body whorl; the spire is depressed and concave, apex acute.

Type locality: None.

H: 19 to 44 mm; W: 55 to 60%; HS: 9 to 17%; AA: 110° to 135°

Habitat: Under dead coral, on sand and reef substrate, in shallow water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: In large specimens the spire is usually eroded, and spiral striae are obsolete; the curved axial striae are well visible on the shoulder whorl. The brown transverse lines are mostly confined to the brown zones and rarely invade the white bands.

61. *Conus terebra* Born, 1778
(Plate 12, Figures 13, 13 a)

1778. *Conus terebra* Born, Test. Mus. Caes. Vindob., p. 162

1791. *Conus terebellum* Gmelin, Syst. Nat., ed. 13, 1: 3390

1798.[?] *Conus albeolus* Röding, Mus. Bolten., p. 47

1807. *Conus fusiformis* G. Fischer, Mus. Demidoff, 3: 144

1843. *Conus coelebs* Hinds, Ann. Mag. Nat. Hist., 11: 256

1881. *Conus thomasi* Sowerby, Proc. Zool. Soc. London, p. 635, pl. 56, fig.4

Shell: Shell narrow, elongate. Body whorl white, cream or very pale yellow, ornamented with two broad, pale yellow transverse bands, one below the shoulder, the other above the base; occasional live-collected specimens lack the yellow transverse bands. The body whorl bears closely set spiral ridges which extend from the base to the shoulder; intervening grooves finely striate; base stained pale violet or violet-brown. Shoulder rounded, smooth, spire moderately elevated, white or pale violet, apex rounded. Aperture narrow, straight, interior white.

Periostracum very thick, smooth, brown.

Juvenile shells are lavender in colour, ornamented with two yellow-green transverse bands; base stained with dark violet, interior of aperture violet, interrupted by a white median band.

Type locality: None. As the species is more frequent in Fiji than elsewhere in its range of distribution, and as a juvenile specimen of *Conus terebra* has been recorded under the name *C. coelebs* Hinds, 1843, from the "Feejee Islands," the Fiji Islands are hereby designated as type locality.

H: 29 to 98 mm; W: 43 to 49%; HS: 10 to 18%; AA: 90° to 110°

Habitat: Under dead coral, on sand and reef substrate, in shallow water. Moderately frequent.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: Dodge (1953) and Habe (1961) referred this species to *Conus clavus* Linnaeus, 1758. Linnaeus' original description in the "Systema Naturae" (1758, p. 716), is far too brief for positive identification and lacks a locality indication as well as a citation to figures. The subdescription added by Linnaeus in the 12th edition (1767, p. 1170) describes a different shell, not his *C. clavus*, and may possibly have been meant for *C. auricomus* Hwass in Bruguière, 1792.

Cotton (1945, 1958) cited *Hermes terebellum* (Linnaeus, 1758) and placed *Conus terebra* Born in synonymy. *Conus terebellum* Linnaeus of the 10th edition was emended to *Bulla terebellum* in the 12th edition. Modern authors treat this species as a member of the genus *Terebellum* Röding, 1798, in the family Strombidae Wenz, 1940.

62. *Conus tessulatus* Born, 1778
(Plate 13, Figure 26)

1778. *Conus tessulatus* Born, Ind. Rer. Nat. Mus. Caes. Vindob., pt. 1, p. 131

1798. *Cucullus pavimentum* Röding, Mus. Bolten., p. 41

1842. *Conus dessellatus* Lamarck, Reichenbach, Na-

turgesch. Land-Süssw.-See Conch., p. 51, pl. 17, figs. 376, 377

1910. *Conus edaphus* DALL, Proc. U.S. Nat. Mus., **38**: 223

Shell: Shell moderately small, solid. Body whorl white, ornamented with transverse rows of bright orange rectangular bars usually arranged to form two bands on the body whorl; base spirally ridged, stained with violet. Shoulder angulate, smooth, spire depressed, concave, apex acute; whorls striate, with a distinct elevated ridge separating the whorls. Aperture slightly narrow, interior white to faint pink, stained with violet anteriorly.

Periostracum orange, thin, smooth.

Type locality: None.

H: 22 to 44 mm; W: 52 to 60%; HS: 9 to 16%; AA: 110° to 135°

Habitat: Buried in patches of sand, in shallow water. Uncommon.

Distribution: Throughout Fiji. - Indo-Pacific.

Discussion: The name of this species is often erroneously spelled as *Conus tesselatus* in literature.

63. *Conus textile* LINNAEUS, 1758

(Plate 13, Figure 23)

1758. *Conus textile* LINNAEUS, Syst. Nat., ed. 10, p. 717, no. 278

1786. *Conus undulatus* SOLANDER, Cat. Port. Mus., p. 180, no. 3866

1792. *Conus archiepiscopus* HWASS in BRUGUIÈRE, Enc. Méth. Vers, **1**: 747

1798. *Cucullus auriger* RÖDING, Mus. Bolten., p. 49

1798. *Cucullus gloria-maris* RÖDING, Mus. Bolten., p. 49 (non *Conus gloria-maris* CHEMNITZ, 1777, non *Conus gloria-maris* HWASS in BRUGUIÈRE, 1792)

1810. *Conus panniculus* LAMARCK, Ann. Mus. Hist. Nat., Paris, **15**: 435

1811. *Conus gloria-maris* PERRY, Conchology, pl. 25, no. 1 (non *C. gloria-maris* CHEMNITZ, 1777, non *C. gloria-maris* HWASS in BRUGUIÈRE, 1792)

1811. *Conus rete-aureum* PERRY, Conchology, pl. 25, no. 5

1858. *Conus scriptus* SOWERBY, Thes. Conch., **3**: 41, pl. 23, fig. 563

Shell: Shell moderately large, thin. Body whorl ornamented with numerous white, trigonal spots of varying sizes, and two to three reddish-orange interrupted transverse bands, the two lower broad transverse bands are marked with blackish-brown, wavy longitudinal lines; body whorl transversely striate. Shoulder rounded, smooth, spire elevated, smooth, concave, maculated with white and reddish-orange, lined with blackish-brown; whorls spirally striate. Aperture wide, flaring basally, lip thin, interior white to pinkish white.

Periostracum thin, smooth, translucent yellow.

Type locality: Bandam, Asiae (Moluccas).

H: 27 to 96 mm; W: 45 to 54 %; HS: 14 to 22%; AA: 90° to 105°

Habitat: Under dead coral, on sand substrate or buried in sand, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: This species is molluscivorous, and has been observed feeding on *Cypraea* and *Conus* in Fiji. According to ENDEAN (1962) the venom of molluscivorous *Conus* species is supposed to have no effect on vertebrates. Other workers (KOHN, SAUNDERS & WIENER, 1960) showed that the venom is highly toxic and often fatal to human beings. KOHN (1963) recorded two deaths and one near fatality from the sting of this species.

Conus textile received a great number of varietal names; they have been omitted from the synonymy.

64. *Conus tulipa* LINNAEUS, 1758

(Plate 15, Figure 38)

1758. *Conus tulipa* LINNAEUS, Syst. Nat., ed. 10, p. 717, no. 282

1798. *Cucullus purpureus* RÖDING, Mus. Bolten., p. 47

1868. *Chelyconus borbonicus* H. ADAMS, Proc. Zool. Soc. London, p. 288, pl. 28, fig. 1

Shell: Shell thin, slightly inflated. Body whorl violet, ornamented with irregular brown blotches, arranged to form two transverse bands; numerous spiral lines consisting of brown and white dashes and dots encircle the body whorl. Base striate, columella concave. Shoulder slightly rounded, smooth, spire low, violet flecked with brown, concave; early whorls finely nodulose, later whorls slightly canaliculate, spirally striate, striae intersected by compressed curved axial striae. Aperture wide, slightly ventricose, flaring basally; interior violet.

Periostracum thin, smooth, translucent yellow.

Type locality: None.

H: 40 to 75 mm; W: 44 to 49%; HS: 7 to 12%; AA: 95° to 115°

Habitat: Under coral, on sand substrate, in deeper water. Rare.

Distribution: West, South and East Viti Levu. - Indo-West Pacific.

Discussion: This species feeds on fishes in nature and is capable of causing fatal injury to human beings; five bites have been recorded, of which three were near fatalities (KOHN, 1963).

65. *Conus varius* LINNAEUS, 1758

(Plate 14, Figure 35)

1758. *Conus varius* LINNAEUS, Syst. Nat., ed. 10, p. 715, no. 270

1798. *Cucullus annularis* RÖDING, Mus. Bolten., p. 40

1798. *Cucullus granulosus* RÖDING, Mus. Bolten., p. 40

1798. *Cucullus radula* RÖDING, Mus. Bolten., p. 40
1828. *Conus interruptus* WOOD, Ind. Test., Suppl., p. 8, pl. 3, fig. 2
1834. *Conus pulchellus* SOWERBY, Conch. Illust., pt. 54, fig. 61 (non *Cucullus pulchellus* RÖDING, 1798, non *Conus pulchellus* SWAINSON, 1822)
1853. *Conus hewassii* A. ADAMS, Proc. Zool. Soc. London, p. 118
1874. *Conus hwassi* WEINKAUFF, Syst. Conch. Cab., (2), Lief. 227, p. 252

Shell: Shell solid, conical. Body whorl white to cream, ornamented with irregular dark brown blotches, and closely set transverse rows of minute pale brown spots and larger dark brown dots; distinct spiral ridges encircle the body whorl, appearing on the anterior half as elevated granules. Shoulder angulate, coronate, spire elevated, coronate, cream in colour; whorls finely striate. Aperture narrow, slightly widening basally, interior whitish to pale yellow.

Periostracum yellowish-brown, smooth, but appearing ridged on occasions, thin, translucent.

Egg capsules are small, oval, ridged, pale brown in colour; capsules measured approximately 8.5 mm in height and 6.5 mm in maximum width; they were deposited on the substrate in parallel rows.

Type locality: None.

H: 28 to 61 mm; W: 46 to 57%; HS: 16 to 24%; AA: 85° to 105°

Habitat: Under dead coral, on reef substrate, in shallow water. Uncommon.

Distribution: Throughout Fiji. - Indo-West Pacific.

66. *Conus vexillum* GMELIN, 1791
(Plate 12, Figure 5)

1791. *Conus vexillum* GMELIN, Syst. Nat., ed. 13, p. 3397
1798. *Cucullus canonicus* RÖDING, Mus. Bolten., p. 43 (non *Conus canonicus* HWASS in BRUGUIÈRE, 1792)
1845. *Conus sulphuratus* KIENER, Spéc. Gén. Icon. Coq. Viv., **2**: 130, pl. 66, fig. 3, & pl. 78, fig. 4

Shell: Shell large, conical. Body whorl white to cream, ornamented with two broad brown transverse bands and longitudinal, undulating dark brown lines; base weakly striate and stained with dark brown. Shoulder angulate, smooth, spire moderately elevated, straight, white flecked with brown; whorls striate. Aperture wide, interior white, lip often waisted centrally.

Periostracum olive-brown, thick, ridged.

Type locality: None.

H: 47 to 92 mm; W: 55 to 63 %; HS: 12 to 19%; AA: 105° to 125°

Habitat: Under dead coral, on sand substrate, and among weed in shallow water. Uncommon.

Distribution: West, South and East Viti Levu. - Indo-West Pacific.

Discussion: Juvenile specimens of this species superficially resemble *Conus capitaneus* LINNAEUS.

67. *Conus* cf. *C. vinctus* A. ADAMS, 1854
(Plate 15, Figures 44, 44 a)

1854. *Conus vinctus* A. ADAMS, Proc. Zool. Soc. London, 1853, p. 118

Shell: Shell short, stout. Body whorl white to bluish-white, ornamented with irregular olive-brown to dark brown longitudinal wavy blotches that are interrupted centrally to form a white transverse band; numerous closely set interrupted dark brown lines encircle the shell. Body whorl spirally striate, striae becoming granulose ridges basally. Shoulder imperceptibly angulate, rounded on occasions, smooth, spire elevated, convex, white flecked with brown; apex papillate and rose-coloured, whorls bear 4 to 5 spiral striae. Aperture somewhat flaring, lip ventricose, interior whitish; marginal edge of lip stained with a few dark grey blotches.

Periostracum orange-brown to olive-brown, minutely ridged, moderately thick.

Type locality: Australia.

H: 24 to 41 mm; W: 54 to 59%; HS: 10 to 16%; AA: 100° to 120°

Habitat: Under dead coral, on reef and sand substrate, in shallow water. Uncommon.

Distribution: Throughout Fiji. - Malaysia, Philippine Islands.

Discussion: This *Conus* species is referred to *C. vinctus* ADAMS with uncertainty as ADAMS never illustrated his new species; his description, however, fits the species recorded from Fiji fairly well. SOWERBY (1857) regarded *C. vinctus* as a minor variety of *C. achatinus* CHEMNITZ (= GMELIN). TOMLIN (1937) stated that there are two types of the species in the British Museum, each measuring 40 mm x 21 mm, which he considered to be *C. monachus* LINNAEUS. ADAMS did not omit to mention the transverse lines of light and dark dots on the body whorl, a feature that is absent in *C. monachus*. The papillate rose-coloured apex, bow-shaped aperture, smaller size and different colour pattern separate the species from *C. achatinus* GMELIN.

Specimens from the Philippine Islands show little variation from those from Fiji. They resemble the species *Conus ranunculus* HWASS in BRUGUIÈRE, 1792, a name adopted by CLENCH (1942) for the West Atlantic species *Conus testudinarius* HWASS in BRUGUIÈRE, 1792. HWASS' type locality of "American Ocean" for *C. ranunculus* should be viewed with suspicion as many Indo-West Pacific species were often confused by the early authors with

somewhat similar-looking West Atlantic species and were given locality indications accordingly.

Reeve (1843, pl. 35, fig. 191 b) and Dautzenberg (1937, fig. 9) illustrated a shell which is a fair likeness of the species under discussion, under the name *Conus achatinus* Hwass var. *ranunculus* Hwass. Dautzenberg considered Hwass' and Lamarck's locality indications for *C. ranunculus* to be erroneous; in this he was joined by Tomlin (1937), who placed *C. ranunculus* in the synonymy of *C. achatinus* Hwass in Bruguière (= Gmelin). It is interesting to note that Gmelin's locality indication for *C. achatinus* was also "American Ocean," although the species does not occur in that region. Future research into this complex species-group may well prove *C. ranunculus* to be an Indo-West Pacific species, identical with the species illustrated.

Specimens of the species discussed here have often been labelled *Conus nigropunctatus* Sowerby, 1857 in collections. Sowerby's description and type figure are too poor for an unequivocal identification. Dr. Kohn (personal communication) viewed the possible types of *C. nigropunctatus* in the British Museum and they appeared to be variants of *Conus achatinus* Gmelin.

Conus cf. *vinctus* is rather common in the Philippine Islands (P. Clover, personal communication).

68. *Conus virgo* Linnaeus, 1758
(Plate 13, Figure 16)

1758. *Conus virgo* Linnaeus, Syst. Nat., ed. 10, p. 713, no. 253
1807. *Conus flavocinctus* Link, Beschr. Nat. Samml. Univ. Rostock, Abtl. 3, p. 103
1858. *Conus coelinae* Crosse, Rev. Mag. Zool., (2), 10: 117, pl. 2, fig. 1

Shell: Shell large, thick. Body whorl yellow, cream or white, transversely striate at base, striae becoming finer and obsolete towards the shoulder; base stained with purple. Shoulder angulate, slightly rounded in very large specimens, smooth, spire slightly elevated, concave to convex, occasionally slightly sub-canaliculate; whorls finely striate. Aperture narrow, only slightly widening basally, interior white with a large purple patch near the base.

Periostracum greenish-brown, smooth, thick.

Juvenile specimens are orange in colour, delicate in texture with a clean, finely sculptured spire that is more distinctly canaliculate than in large adults.

Type locality: Africano oceano.

H: 38 to 150 mm; W: 50 to 59%; HS: 7 to 13%; AA: 120° to 135°

Habitat: In patches of sand, under dead coral on sand substrate, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

Discussion: Demond (1957) reported the species from Hawaii, where it does not occur. *Conus spiceri* Bartsch & Rehder (1943), which appears to be endemic to Hawaii, is somewhat similar to *C. virgo*, but always lacks the dark purple stain at the base.

69. *Conus vitulinus* Hwass in Bruguière, 1792
(Plate 14, Figure 32)

1792. *Conus vitulinus* Hwass in Bruguière, Encycl. Méth. Vers, 1: 648
1829. *Conus vulpinus* Schubert & Wagner, Syst. Conch. Cab., 12: 56, pl. 222, fig. 3073 (non *C. vulpinus* Hwass in Bruguière, 1792)

Shell: Shell solid, conical. Body whorl reddish-brown, ornamented with two white transverse bands at shoulder and center; reddish-brown streaks often intrude into the white transverse bands. Body whorl spirally striate, striae distinctly ridged and granulose basally, becoming obsolete towards the shoulder; base stained with dark brown. Shoulder angulate, smooth, spire depressed, alternately flecked with white and brown, concave to convex; whorls spirally striate, slightly canaliculate in some specimens. Aperture narrow, interior white.

Periostracum thick, brown, ridged, tufted.

Type locality: Indian Ocean.

H: 20 to 65 mm; W: 54 to 60%; HS: 4 to 11%; AA: 125° to 150°

Habitat: Under dead coral, on reef substrate, in shallow water. Common.

Distribution: Throughout Fiji. - Indo-West Pacific.

70. *Conus* species
(Plate 15, Figures 45, 45 a)

Shell: Shell solid, broad. Body whorl bluish-grey, ornamented with small subtrigonal and elongated nebulous white blotches, becoming larger and merging, to form a narrow whitish central band; edge of shoulder encircled with a row of small subtrigonal blotches. Interrupted blackish-brown transverse lines encircle the body whorl, which is spirally striate; striae appear as widely spaced distinct ridges near the base, becoming fine and closely set towards the shoulder. Columella with a slight fold anteriorly, base white. Shoulder slightly angulate, subcanaliculate, smooth, spire elevated, straight to convex, bluish grey, axially maculated with white; apex pointed, each whorl with 2 distinct spiral threads. Aperture wide, slightly flaring basally, interior white or pale bluish-white, with the marginal edge of the lip occasionally lined and spotted with blackish-brown.

H: 40 to 62 mm; W: 52 to 59%; HS: 10 to 15%; AA: 105° to 115°

Habitat: Under dead coral, on sand and reef substrate, in shallow and deeper water. Rare.

Distribution: South Viti Levu. - Philippines.

Discussion: It is impossible to reach a satisfactory conclusion as to the true taxonomic status of this species without thorough study and reference to type specimens, if at all extant. The species is obviously related to the complex group of forms comprising *Conus monachus* LINNAEUS, 1758, *C. achatinus* GMELIN, 1791, and *C. ranunculus* HWASS in BRUGUIÈRE, 1792.

The species *Conus monachus* LINNAEUS was recently studied by KOHN (1963 b) and unequivocally established as a valid species; the author selected the REGENFUSS figure, which was one of LINNAEUS' references, as being representative of the lectotype (*ibid,* pl. 3, fig. 26), and also reproduced a specimen of *C. monachus* from the "Museum Ulricae" collection (pl. 3, fig. 27). These two figures leave no doubt that *C. monachus* is a shell lacking the closely set transverse lines composed of dots and dashes on the body whorl; the presence of such ornamentation rules out the species from Fiji.

Conus nebulosus GMELIN, 1791, which was at first thought to apply to the Fiji specimens, was found to be an absolute synonym of *C. monachus* LINNAEUS. GMELIN's references for his *C. nebulosus* were BUONANNI (1684, fig. 126), and REGENFUSS (1758, pl. 12, fig. 68); both these citations were referred to by LINNAEUS for his *C. monachus.* GMELIN, however, separated *C. monachus* from his *C. nebulosus*; for variety "β" of *C. monachus* he refers to CHEMNITZ (1788, pl. 142, figs. 1319, 1320). These figures were regarded by DODGE (1953) as possibly representing either *C. catus* HWASS in BRUGUIÈRE, 1792, or the "Minime" of pre-Linnean authors. HWASS (1792), the author of *C. catus,* refers to figure 1320 for his *C. achatinus.* REEVE (1843) cited the same figure and associated it with *C. monachus franciscanus* of CHEMNITZ; for unknown reasons REEVE made it a variant "β" of *C. cinereus* HWASS in BRUGUIÈRE, 1792.

TOMLIN (1937) considered *Conus achatinus* to be a synonym of *C. monachus.* GMELIN (1791, p. 3386) described *C. achatinus* as an elongated shell with a short spire and reddish apex, details which do not agree with Fiji specimens of *Conus* species. GMELIN's *C. achatinus* appears to be a composite species, consisting of *C. achatinus* and *C. magus* LINNAEUS. GMELIN's reference for his variation "δ" of *C. achatinus* was CHEMNITZ (1788, pl. 142, fig. 1317), which was the "*C. achatinus maximus*" of CHEMNITZ and of authors, from the East Indian Seas. The remaining GMELIN references represent either *C. magus,* or may be interpreted either way. One other of GMELIN's citations was to MARTINI's "Achaat" (1773, pl. 52, figs. 579, 580), of which figure 579 could possibly represent *C. achatinus* of authors, but figure 580 is one of the many forms of *C. magus.*

DILLWYN (1817), PFEIFFER (1840), and DAUTZENBERG (1937) refer these MARTINI figures to *C. magus* LINNAEUS.

HWASS (1792, p. 671) does not refer to GMELIN nor to any of GMELIN's citations for his *C. achatinus.* Despite the fact that one of HWASS' references (CHEMNITZ, 1788, pl. 142, fig. 1320) had been interpreted in many ways, his *C. achatinus* is at any rate more clearly defined than GMELIN's.

DILLWYN (1817) lists *Conus achatinus* CHEMNITZ, with *C. achatinus* HWASS in BRUGUIÈRE, and *C. minimus* GMELIN, 1791 (non LINNAEUS, 1758) in synonymy; he further remarks that GMELIN's *C. achatinus* is *C. magus* LINNAEUS.

DAUTZENBERG (1937) places GMELIN's varieties of *Conus achatinus* with *C. achatinus* HWASS in BRUGUIÈRE in the synonymy of *Conus achatinus* CHEMNITZ and he refers *Conus achatinus* GMELIN to *Conus magus* LINNAEUS, thus following DILLWYN. The species *Conus ranunculus* HWASS in BRUGUIÈRE, 1792, was regarded as a variety of *Conus achatinus,* both by REEVE (1844) and DAUTZENBERG (1937); the latter pointed out that the American locality cited by HWASS and LAMARCK is in error. CLENCH (1942) accepts the American locality as correct and restricts *C. ranunculus* to the Lesser Antilles, the North coast of South America and West Africa. If we were to accept GMELIN's locality of "Oceano Americano" for his *C. achatinus* as correct, then his shell can be neither *C. achatinus* HWASS in BRUGUIÈRE, nor *C. magus* LINNAEUS.

As stated previously, TOMLIN (1937) associated *Conus achatinus* HWASS in BRUGUIÈRE with *C. monachus* LINNAEUS. REEVE (1844), however, stresses the absence of the transverse lines and dots in *C. monachus,* a feature present in *C. achatinus;* the recently established lectotype of *C. monachus* confirms REEVE's correct interpretation of the species.

MERMOD (1947) in his work on the HWASS - LAMARCK - DE LESSERT collection preserved in Geneva, interprets *Conus achatinus* as the rather globular, greenish-bluish shell with numerous fine punctate or dotted transverse lines of dark and light dots, a shell currently accepted as that species. Specimens of *C. achatinus* used for comparison show that this species, when compared with *Conus* species from Fiji, is lighter in weight, more narrow in shape (50% of height), with a proportionately higher spire (17% of height) and an apical angle of 95°. The transverse lines on the body whorl alternate in white and brown dots and lines, whereas in *Conus* species the lines are entirely blackish-brown and only occasionally interrupted by a nebulous white dot from the main design. The most important morphological feature of *C. achatinus* are the 4 to 5 fine spiral striae on each whorl of the

spire. "*Conus* species", however, bears two distinct spiral threads on each whorl; a comparison of Fiji and Philippine Island specimens showed no variation in this respect. *Conus achatinus* lacks the distinct narrow whitish central band and the "hem-like" band at the shoulder of "*Conus* species."

In view of the conflicting evidence I hesitate to assign this to any of the species mentioned in the foregoing discussion.

UNCONFIRMED RECORDS OF *Conus* FROM THE FIJI ISLANDS

Conus aplustre Reeve, 1843 - Conch. Icon., 1, pl. 30, spec. 170. Reported by Cotton (1945).

Conus auricomus Hwass in Bruguière, 1792 - Encycl. Méth. Vers, 1: 742. Reported by Cotton (1945) under the name *Hermes clavus* (Linnaeus).

Conus coccineus Gmelin, 1791 - Syst. Nat., ed. 13, p. 3390. Reported by Cotton (1945).

Conus gubernator Hwass in Bruguière, 1792 - Encycl. Méth. Vers, 1: 727. Reported by Cotton, (1945).

Conus lienardi Bernardi & Crosse, 1861 - Journ. Conchyl. Paris, 9: 49, pl. 1, fig. 2. Reported by Cotton, (1945).

Conus monachus Linnaeus, 1758 - Syst. Nat., ed. 10, p. 714, no. 262. Reported by Cotton (1945).

Conus ochroleucus Gmelin, 1791 - Syst. Nat., ed. 13, p. 3391. Reported by Cotton (1945).

Conus parius Reeve, 1844 - Conch. Icon., 1, pl. 43, spec. 235. Reported by Cotton (1945).

Conus sulcatus Hwass in Bruguière, 1792 - Encycl. Méth. Vers, 1: 618. Reported in Gifford (1951), by Hertlein & Hanna.

Conus sumatrensis Hwass in Bruguière, 1792 - Encycl. Méth. Vers, 1: 655. Reported in Gifford (1951), by Hertlein & Hanna.

Discussion: The occurrence of *Conus auricomus* Hwass in Bruguière in Fiji is highly probable as the species appears to have a continuous distribution from Hawaii to the Philippine Islands and Malaysia. The species must be extremely rare in Fiji as no authentic specimens have been collected so far.

Conus ochroleucus Gmelin does not occur in Fiji: however, a very similar species, *C. radiatus* Gmelin does live there. *Conus sulcatus* and *C. sumatrensis* were identified by Hertlein & Hanna from collections of shell-middens of ancient Fijian village sites. Such shells are usually in very poor condition, usually lacking colour and pattern, and a positive identification is often impossible. Small specimens of *C. vexillum* Gmelin closely resemble *C. sumatrensis*. The two species recorded by Gifford and identified by Hertlein & Hanna do not occur in Fiji waters.

FOSSIL RECORDS OF *Conus* FROM THE FIJI ISLANDS

Conus affinis Martin, 1879, Ladd, 1934, Bernice Bish. Mus. Bull., **119**: 231, pl. 41, fig. 3

The species was reported by Ladd from the Miocene deposits of Viti Levu. Martin's *Conus affinis* is a homonym of *C. affinis* Gmelin, 1791, and was renamed *C. sannio* Finlay, 1926. It appears that the Fijian fossil record does not belong to the genus *Conus*.

Conus pulicarius Hwass, 1792, Ladd, 1934, Bernice Bish. Mus. Bull., **119**: 231, pl. 41, fig. 4

Ladd's specimen from the Miocene (Pliocene?) of Viti Levu, tentatively identified as *Conus pulicarius* Hwass certainly is not that species. The illustrated specimen compares favorably with the recent species *C. aristophanes* Sowerby.

Conus species B. Ladd, 1934, Bernice Bish. Mus. Bull., **119**: 232, pl. 41, fig. 5

Ladd compared the species from the Miocene (Pliocene?) of Viti Levu with Australian examples of *Conus anemone* Lamarck, 1810. The illustration shows a shell with an extremely high spire, composed of 5 whorls, and a mammillated apex; the juncture of the aperture is well below the shoulder. The fossil species has no affinity with the recent species *C. anemone*, and in shape, spire and sculpture only slightly resembles *C. compressus* Sowerby, 1866, or *C. tannaensis* (Cotton, 1945). It is in all probability a distinct species.

APPENDIX

Through the kindness of Mr. P. W. Clover of San Antonio, Philippine Islands, I received several *Conus* shells for comparison with Fiji specimens.

The material forwarded for examination contained one specimen of *Conus dilectus* Gould; the shell was collected by Mr. Clover at Batangas, Philippine Islands, and measured 15.2 mm by 7.7 mm. The specimen agreed very well with the Fiji specimen illustrated, except that the transverse striae on the body whorl were more prominent and extended farther towards the shoulder. This new geographical record extends the distributional range of the species.

A series of *Conus* specimens collected in the Philippine Islands by Mr. Clover were undoubtedly identical with specimens of *Conus lachrymosus* Reeve from Fiji. The Philippine shells showed the same high degree of varia-

bility as those recorded from Fiji. The largest specimen measured 34.6 mm by 18.1 mm, and agreed fairly well with the description and type figure of *Conus boeticus* REEVE (1844, pl. 42, spec. 226). REEVE's diagnosis of *C. boeticus* does not appear to be typical of the species and REEVE may have been guilty of describing a variant of a specimen, instead of a species. Whatever the case may be, the shells from the Philippine Islands strongly suggest that *C. boeticus, C. lachrymosus* and *C. rivularius* REEVE are connected through various intermediate specimens and are conspecific.

Mr. Clover (personal communication) confirmed that the periostracum of the Philippine Island shells is identical with the periostracum of Fiji specimens of *Conus lachrymosus*. Animal and egg-case descriptions of the species from the Philippine Islands and a comparison with the species listed as *C. lachrymosus* REEVE from Fiji may prove the latter species to be only an infraspecific form of *C. boeticus* REEVE.

CONCLUSION

A total of 70 species of *Conus* have been recorded from recent collections; an additional 10 species have been recorded in literature, but in view of the uncertainty of positive locality indication and identification, they are treated as unconfirmed reports.

Statistical measurements show that the width of the shell in relation to its height does not exceed 12% in the various populations of *Conus* examined from Fiji; it is interesting to note that shells of the genus *Cypraea* display a similar variation in form.

Although individuals of two closely related species are sometimes separated with difficulty, measurements of large series of shells will often bring to light constant differences in a certain measurable dimension (the width of *Conus mustelinus* as compared with *C. capitaneus*). Pathological specimens of *Conus*, e. g. shells with a double shoulder or a dropped shoulder, may often fall outside of the accepted limits of variation.

LITERATURE CITED

ADAMS, ARTHUR

1854. Descriptions of new species in the genus *Conus*; from the collection of Hugh Cuming, Esq. Proc. Zool. Soc. London **21**: 116 - 119 (14 Nov. 1854)

BUONANNI, FILIPPO

1684. Recreatio mentio et oculi in observatione animalium testaceorum curiosis naturae inspectoribus. Rome, pts. 1 - 3, 139 plates.

CERNOHORSKY, WALTER OLIVER

1964. The Cypraeidae of Fiji (Mollusca: Gastropoda). The Veliger **6** (4): 177 - 201; plts. 21 - 26; 1 Text fig.; 1 map (1 April 1964)

CHEMNITZ, JOHANN HIERONYMUS

1788. Neues systematisches Conchylien-Cabinet (continuation of F. H. W. Martini). Nürnberg, **10** (1): plts. 138 - 143

CLENCH, WILLIAM JAMES

1942. The genus *Conus* in the western Atlantic. Johnsonia **1** (6): 1 - 40; 15 plts.

COTTON, BERNARD CHARLES

1945. A catalogue of the cone shells (Conidae) in the South Australian Museum. Rec. South Austral. Mus. **8** (2): 229 to 280; 5 plts.; 1 text fig.

1958. Australian Recent and Tertiary species of the molluscan family Conidae. Roy. Soc. South Austral., Malac.Sect., Adelaide, 1 plt. (not paginated)

DAUTZENBERG, PHILIPPE

1937. Résultats scientifiques du voyage aux Indes Orientales Néerlandaises; Gastéropodes marins; Conidae. Mém. Brux. Mus. Roy. d'Hist. Nat., **2** (18): 1 - 284; plts. 1 - 3

DEMOND, JOAN

1957. Micronesian reef-associated gastropods. Pacif. Sci., **11** (3): 275 - 341; plts. 1 - 4; text figs. 1 - 42; 1 table

DILLWYN, LEWIS WESTON

1817. A descriptive catalogue of recent shells, arranged according to the Linnaean method, with particular attention to the synonymy. London, **1**: 1 - 580; **2**: 581 - 1092; index

DODGE, HENRY

1953. A historical review of the mollusks of Linnaeus. Pt. 2, the class Cephalopoda and the genera *Conus* and *Cypraea* (Gastropoda). Bull. Amer. Mus. Nat. Hist.**103** (1): 1 - 134

ENDEAN, R.

1962. A survey of venomous cones. Austral. Newsletter, Malac. Soc. Austral., **11** (43): 1 - 11

GIFFORD, E. W.

1951. Archaeological excavations in Viti Levu. Anthrop. Rec., **13** (3): 189 - 288; figs.; maps.

GMELIN, J. F.

1791. Caroli Linnaei systema naturae per regna tria naturae. Editio decima tertia. Leipzig, vol. **6**.

HABE, TADASHIGE

1961. Coloured illustrations of the shells of Japan. **II**: 1 to 183; 66 colored plates.

HANLEY, SYLVANUS CHARLES

1855. Ipsa Linnaei Conchylia: the shells of Linnaeus, determined from his manuscripts and collections. London, 556 pp.; 6 plts.

HANNA, G DALLAS

1963. West American molluscs of the genus *Conus;* II. Calif. Acad. Sci. Occ. Papers **35**:1 - 103; plts 1 - 11 (28 Jan. 1963)

HWASS, CHRISTIAN HEE (in BRUGUIÈRE)

1792. Encyclopédie méthodique. Histoire naturelle des Vers. Panckoucke, Paris, **1** (2): 345 - 757

IREDALE, TOM

1930. Queensland molluscan notes, No. 2. Mem. Qld. Mus., **10** (1): 73 - 88; plt. 9

KIENER, L. C.

1845-1850. Spécies général et iconographie des coquilles vivantes; famille des Enroulées, genre Cone. Rousseau, Paris, **2:** 1 to 379; plts. 1 - 111

KIRA, TETSUAKI

1959. Coloured illustrations of the shells of Japan. Rev. ed., Hoikusha, Osaka, **1:** 1 - 239; 71 plts.

KOHN, ALAN J.

1959. The Hawaiian species of *Conus* (Mollusca: Gastropoda). Pacific Sci., **13:** 368 - 401; 2 plts.; 4 text figs.

1961. Studies on spawning behaviour, egg masses, and larval development in the gasteropod genus *Conus*. II. Observations in the Indian Ocean during the Yale Seychelles expedition. Bull. Bingham Ocean. coll., Peabody Mus. Nat. Hist., Yale Univ., **17** (4): 3 - 51; 10 tables; 26 text figs.

1963. Venomous marine snails of the genus *Conus*; in: Venomous and poisonous animals and noxious plants of the Pacific area. Pergamon Press, Oxfr., 83-96; 4 text figs.; 3 tab.

1963 a. *Conus clavus* LINNAEUS, 1758; *Conus minimus* LINNAEUS, 1758; *Conus rusticus* LINNAEUS, 1758; and *Conus senator* LINNAEUS, 1758 (Mollusca, Gastropoda); proposed suppression under the plenary powers, Z. N. (S) 1558. Bull. zool. Nomencl., **20** (4): 309 - 312

1963 b. Type specimens and identity of the described species of *Conus*. I. The species decribed by Linnaeus, 1758 - 1767. Journ. Linn. Soc. Zool. London, **44** (302): 740 - 768; 4 plts.

KOHN, ALAN J., PAUL R. SAUNDERS & S. WIENER

1960. Preliminary studies on the venom of the marine snail *Conus*. Ann. New York Acad. Sci., **90** (3): 706 - 725; 7 text figs.; 10 tables

KOHN, ALAN J., & CLIFTON S. WEAVER

1962. Additional records and notes on *Conus* (Mollusca: Gastropoda) in Hawaii. Pacific Sci., **16** (4): 349 - 358; 5 text figs.

LADD, S. HARRY

1934. Geology of Viti Levu, Fiji. Bernice P. Bishop Mus. Bull. **119:** 1 - 263; plts. 1 - 44

LINNAEUS, CAROLUS

1758. Systema naturae per regna tria naturae. Tenth Edit. Brit. Mus. facsimile reprod.

1764. Museum s:ae r:ae m:tis Ludovicae Ulricae Reginae Svecorum. L. Salvii, Holmiae, pt. 2: 1 - 722

1767. Systema Naturae per Regna Tria Naturae. Ed. 12, Holmiae, **1**, pt. 2

MARTINI, FRIEDRICH HEINRICH WILHELM

1773. Neues systematisches Conchylien-Cabinet. Nürnberg, **2** (1), plts. 52 - 64

MERMOD, GASTON

1947. Catalogue des types et des exemplaires de Cones figurés ou décrites par Hwass, Bruguière, Lamarck, de Lessert, Kiener et Chenu, se trouvant au Musée de Genève. Rev. Suisse Zool. **54:** 155 - 217

MONTFORT, DENYS DE

1810. Conchyliologie systématique et classification méthodique des coquilles. Paris, 2 vols.

MÖRCH, OTTO ANDREAS LOWSON

1852-1853. Catalogus conchyliorum quae reliquit D. Alphonso d'Aguirra et Gadea, Comes de Yoldi. Hafniae, fasc. **1:** 1 - 170

PFEIFFER, LOUIS

1840. Kritisches Register zu Martini und Chemnitz, Systematisches Conchylien-Cabinet. Kassel; pp. 1 - 112

QUOY, JEAN RENÉ CONSTANT, & JOSEPH PAUL GAIMARD

1834. Voyage de la Corvette l'Astrolabe exécuté par ordre du Roi, pendant les années 1826-1829, sous le commandement de M. J. Dumont d'Urville; Mollusques. Zoologie, Paris, **3:**; 95 plates

REEVE, LOVELL AUGUSTUS

1843-1844. Conchologia Iconica; a complete repertory of species. Monograph of the genus *Conus*. London, **1**; plts. 1 - 47

1848 - [1849]. Conchologia iconica; or illustrations of the shells of molluscous animals. London, Monograph of the genus *Conus*, suppl.: 1 - 7; plts. 1 - 9.

REGENFUSS, FRANZ M.

1758. Auserlesne Schnecken, Muscheln und andre Schaalthiere. Copenhagen, Andreas Hartwig Godiche. pp. 1 - 14, 1 - 22, 1 - 87; plts. 1 - 12

RUMPHIUS, GEORGE EVERHARD

1705. D'Amboinsche Rariteitkamer. Amsterdam, plts. 1 - 60

SOWERBY, GEORGE BRETTINGHAM

1857-1858. Thesaurus Conchylorum; Monograph of the genus *Conus*. London, 3 (18): 1 - 56; plts. 1 - 24 (187 - 210)

SWAINSON, WILLIAM

1840. A treatise on malacology, or the natural classification of shells and shellfish. London, pp. 1 - 419; text figs.

TOMLIN, JOHN READ LE BROCKTON

1937. Catalogue of Recent and fossil cones. Proc. Malacol. Soc. London, **22:** 205 - 330; addenda, p. 333.

Discussion of the *Mytilus californianus* Community on Newly Constructed Rock Jetties in Southern California

(Mollusca: Bivalvia)

BY

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(3 Text figures)

INTRODUCTION

The California sea-mussel, *Mytilus californianus* Conrad, 1837, is distributed from the Aleutian Islands, Alaska, to Isla Socorro, Mexico (110° 55′ W. Longitude and 18° 45′ N. Latitude). It is particularly abundant on rocks in the intertidal zone of the more exposed coasts (Soot-Ryen, 1955). The re-establishment of a *M. californianus* community was studied by Hewatt (1935) at Monterey, California. He scraped an area free of all macroscopic life and studied the settlement of organisms on this denuded rock during the ensuing 2.5 years. Evidence for true succession was found; some of the earliest inhabitants were essential for the settlement of some of the later organisms. The study of succession by scraping a rock and following the settlement of organisms has been pursued by others, for example, Bokenham & Stephenson (1938) and Hoshiai (1960).

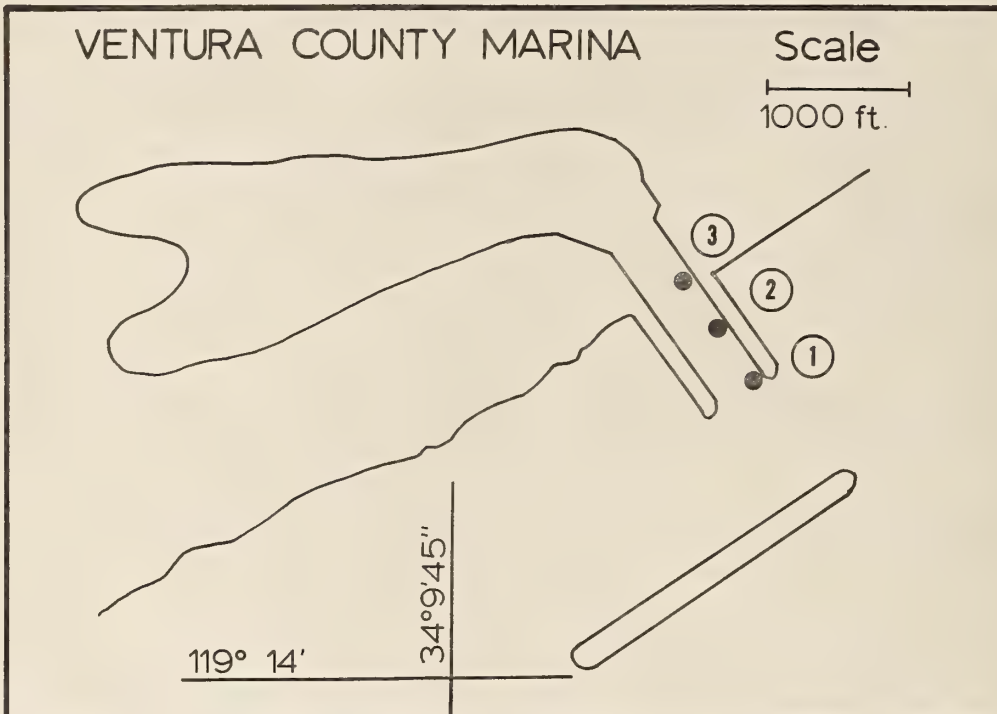
The construction of new boat harbors in southern California has provided opportunities to study settlement of organisms on new structures never before exposed to sea water. Rock jetties are built on both sides of the entrance (Figures 1 and 2) in order to minimize the wave action within the marina and to prevent offshore sediments from being deposited within the boat harbor. The settlement of organisms, especially *Mytilus californianus*, on these jetties was studied at Ventura County (Port Hueneme) and Playa del Rey (Los Angeles) Marinas (Figures 1 and 2). This paper reports the results of these observations.

MATERIALS and METHODS

The rock jetties at Ventura County and Playa del Rey Marinas were constructed in a similar manner. Two trenches were excavated in the sandy beach to a required depth and then filled with large rocks. Afterwards the jetty was extended beyond the coast line. The sand between the two jetties was not removed for about a year; in other words, only that portion of the jetty which extended beyond the coastline was exposed initially to sea water. Collections were first made in June and July 1960, at Ventura and Playa del Rey Marinas, respectively, or about 3 to 4 months after the rocks were first exposed to sea water. Collections were made approximately bimonthly until the end of the study in June 1962. As the dredging of the land between the jetties proceeded, the rocks were first exposed to sea water at a different time of the year. Therefore, it was possible to determine what effect, if any, the time of year has on the colonization of organisms on the rocks.

Collections were made from the mid-tide horizon where the *Mytilus californianus* community reached its maximum development. Successive collections were either made from the same rock or an adjoining one. An area associated organisms. Specimens were preserved in the field. The animals were sorted, identified, weighed and measured in the laboratory.

Three collecting sites were selected on the south jetty of Ventura County Marina (Figure 1): Site 1 was first exposed approximately March 1, 1960, the first collection



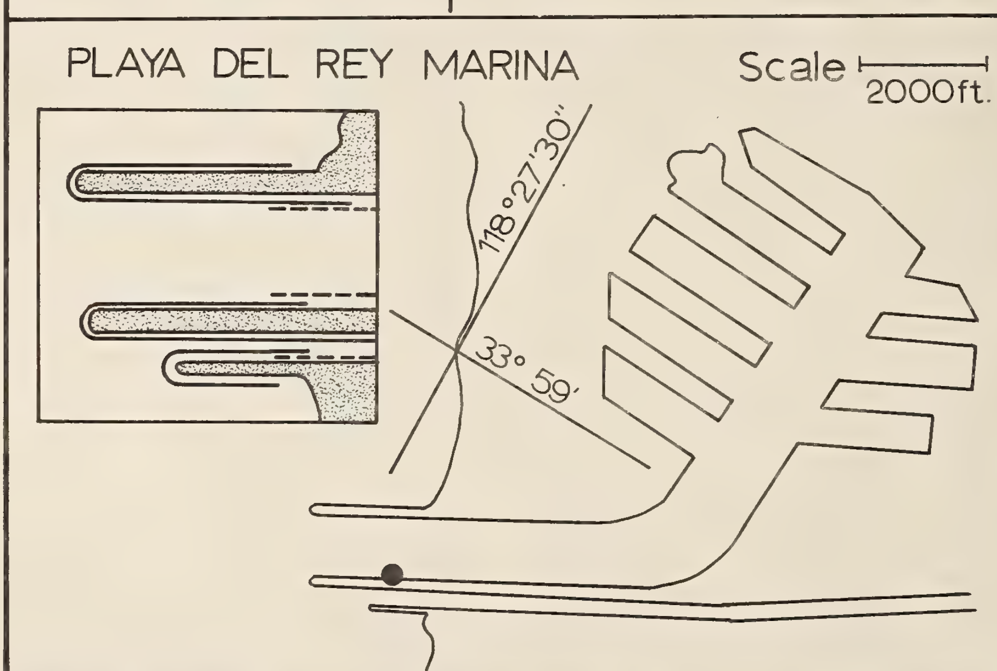


Figure 1: Map of Ventura County Marina, California, showing station locations.

Figure 2: Map of Playa del Rey Marina, California, showing collecting site. Distribution of *Mytilus californianus* is indicated by solid line and of *M. edulis* by dotted line.

made on June 17, 1960, and Sites 2 and 3 were first exposed approximately September 1 to 15, 1960, the first collections made on December 14, 1960. Only one site was used at Playa del Rey; it was first exposed approximately April 1, 1960, and the first collection made on July 1, 1960. Observations were made periodically inland to the collecting site especially for signs of *Mytilus californianus.*

ACKNOWLEDGMENTS

The author wishes to thank Mr. Ira M. Cornwall and Dr. E. Yale Dawson for assistance in the identification of some of the barnacles and algae, respectively. The author thanks Miss Emilie Bender, Mrs. Bettye Byrne, Miss Ruth Zakem, and Mr. Harold Pope, for sorting the organisms collected in this study.

VENTURA COUNTY MARINA

The green alga, *Ulva dactylifera* SETCHELL & GARDNER, 1920, was the earliest macroscopic organism to settle on the rock jetties at both marinas. Luxuriant growths were observed throughout the mid-tide horizon within two months after the rocks were first exposed to sea water in spring 1960. The algae began to diminish shortly thereafter. *Ulva dactylifera* completely disappeared from Site 1 at both Ventura County and Playa del Rey Marinas after seven months exposure.

Settling of *Mytilus californianus* was rapid on the newly constructed jetties (Figure 3, Table 1). A peak of 1540 specimens for the 400 cm² area was reached by the end of summer 1960. The number of mussels decreased during the winter of 1960-61; a second peak of 1535 specimens was reached during August 1961. Thereafter the number of specimens continued to decrease until the entire population of *M. californianus* had been completely eliminated by August 1962, at Ventura. No mussels have been seen at Site 1 in Ventura County Marina since the summer of 1962, although a population is located nearby at the end of the jetty (see discussion).

The curve for the weight of the population of *Mytilus californianus* follows the trend of number of specimens during 1960. A plateau in the biomass occurred during the winter 1960-61 rather than a decrease as observed in the number of specimens; therefore, the weight per individual increased during this time. The weight of the population showed a second rise during the spring and summer of 1961 with a maximum weight of 1453 grams measured in August 1961. The weight of the population, but not per specimen, remained relatively constant during the next year.

Growth of the population of *Mytilus californianus*, as determined by the shell length of the largest specimens in each collection, proceeded at a regular rate of 6 mm per month for the first year ending February 24, 1961. (Actually, this figure of 6 mm per month is a conservative one since the year was figured from March 1, 1960, the approximate date that Site 1 was first exposed to sea water. It is highly unlikely that *M. californianus* settled on the rocks the first day. The exact date the mussels first settled on the jetty is, of course, unknown; therefore, the conservative estimate was used.) No specimens were collected greater than 70 mm in length.

Sites 2 and 3 (Figure 1) at Ventura County Marina were originally exposed to water September 1 to 15, 1960. Growth of *Ulva dactylifera* dominated the entire mid-tidal zone from December 14, 1960 to April 2, 1961. *Mytilus californianus* were first seen at Site 2 on April 12, 1961. A total of 904 specimens, weighing 288 grams, and measuring up to 18 mm in length, was collected from a 400 cm² area on April 12, 1961. This was the largest population of mussels seen at this site. Small clumps of mussels were observed for the next six months, but none were seen after October 6, 1961. The population had not been re-established by July 1963. A few specimens of *M. californianus* were observed on the side of rocks at Site 3 on June 6, October 6, and December 19, 1961, but none since. A few small specimens of *M. edulis* LINNAEUS, 1758, were taken here on June 26, 1962, but none after this date.

PLAYA DEL REY MARINA

The growth and development of the *Mytilus californianus* community at Playa del Rey Marina was similar to what was observed at Ventura County Marina. As stated above, *Ulva dactylifera* preceded the establishment of the mussel. One striking difference in the mussel community in the two marinas was noted; the population of *M. californianus* has persisted to date at the jetties at Playa del Rey. An overlapping population of *M. californianus* and *M. edulis* was observed on each side of the rock jetties at Playa del Rey. The distribution of these two species of mussels is diagrammed in Figure 2.

ASSOCIATED SPECIES

The principal species of plants and animals associated with the population of *Mytilus californianus* are listed in Table 1. Seasonal differences are noted with respect to the number of species and specimens. The larger and more diverse populations were encountered during the summer and smaller, less diverse populations were observed during the winter months. The majority of the known species collected show a seasonal peak in occurrence. For example, the polychaetes *Nereis grubei* (KINBERG, 1866), *Lumbrineris zonata* (JOHNSON, 1901), and *Boccardia proboscidea* HARTMAN, 1940, were collected

Table 1

List of species and number of specimens collected from the *Mytilus californianus* community on the rock jetty at Ventura County Marina

Species	6/17 1960	8/4 1960	9/30 1960	12/14 1960	2/14 1961	4/12 1961	6/6 1961	8/3 1961	10/6 1961	12/19 1961	6/26 1962
Phylum Chlorophyta											
**Ulva dactylifera*	+	+				+					+
*Phylum Coelenterata											
sea anemones, unidentified					1	5	2	6	7		8
*Phylum Platyhelminthes											
unidentified		2	6	1	9	7	1	14	16	14	146
*Phylum Nemertea											
unidentified	1	4	1	2	3		24	16	10	8	315
Phylum Annelida; Class Polychaeta											
Paleonotus bellis								2			24
*Phyllodocid			3	14	1			1	4		
*Syllinae	1	3	51	18	6	10	1	198			305
**Nereis grubei*	1	1	1				1	1			
**Nereis latascens*		7	3								
Glycera sp.						1		2	3		
**Lumbrineris zonata*			1					4	1		1
Dorvillea articulata							3				1
**Naineris dendritica*			20					3	6	10	22
**Boccardia proboscidea*		12	407				20	5			1
**Cirriformia luxuriosa*			5					1	9	10	
**Polyophthalmus pictus*		2	90		4		1	6	74	62	
**Capitella capitata*		1	30					2			
Phragmatopoma californica							6	4			1
**Chone sp.*			7					5			2
Phylum Sipunculoidea											
Phascolosoma agassizii			3			1	3	45	20	26	4
Phylum Arthropoda; Class Crustacea											
Pachygrapsus crassipes		1						1	1	4	2
**Balanus crenatus*		4			10			27	42	64	440
**Chthamalus dalli*								70	46	281	21
**Mitella polymerus*			4	9	3			2	1		41
Phylum Mollusca; Class Pelecypoda											
**Hiatella arctica*	1	9	10	1	1		7	19		5	30
**Mytilus californianus*	141	645	1540	929	934	1219	900	1535	1126	796	559
**Protothaca staminea*					1		4		10		22
*Clams, juvenile			3					1			
Class Gastropoda											
**Acmaea digitalis*								5		5	
**Acmaea limatula*								55	41	15	23
**Acmaea sp.*, juvenile		35	42	12	18	2	30	7			
**Littorina planaxis*			1		2		1				
Littorina scutulata		2	2							4	
Tegula sp.						8	5	5			
*Snails, juvenile							19	19	5	8	7
Additional species	0	1	3	1	0	0	1	0	1	4	6
Additional specimens	0	1	4	1	0	0	1	0	1	5	5+
Total number of species	6	16	24	9	13	9	18	29	19	19	28
Total number of specimens	145	729	2224	987	993	1253	1029	2051	1423	1357	1980
Total number of specimens excluding *Mytilus californianus*	4	84	684	58	59	34	129	516	297	561	1421

* Indicates species also present in the *Mytilus californianus community* on the jetty at Playa del Rey Marina.

only during the months of June through October. The two acorn barnacles, *Balanus crenatus* BRUGUIÈRE, 1789, and *Chthamalus dalli* PILSBRY, 1916, were not taken in large numbers until 14 months after the first mussels were collected. Limpets were present the first summer, but the specimens were too small to make specific identifications. *Acmaea limatula* CARPENTER, 1864, was the most frequently encountered limpet in 1961.

Some species were incidental inhabitants of the mussel community and present more abundantly elsewhere. The polychaete *Phragmatopoma californica* (FEWKES, 1889) builds sandy tubes which formed a conspicuous community in the low intertidal zone at Ventura County Marina. All specimens of the crab *Pachygrapsus crassipes* RANDALL, 1839, were small; the adults were very abundant between the rocks in the intertidal zone. All specimens of the clam *Protothaca staminea* (CONRAD, 1837) were small; this species was more commonly encountered in the benthos.

Additional species were collected, in most cases only one or two specimens and not listed in Table 1, from the *Mytilus californianus* community at Ventura County;

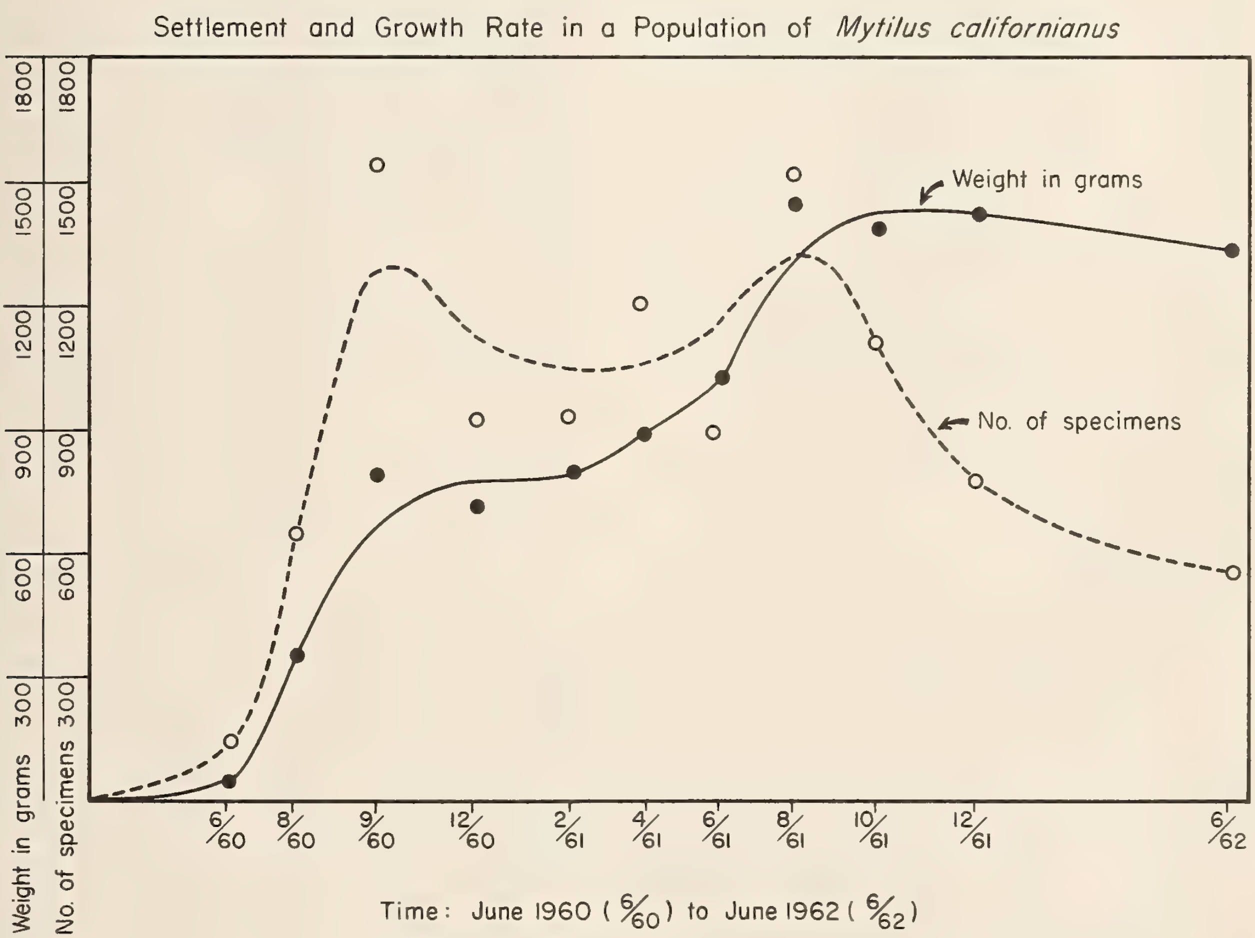


Figure 3: Graph showing settlement and growth rate of a population of *Mytilus californianus* in Ventura County Marina, California.

these include an unidentified sponge, the polychaetes *Halosydna johnsoni* (Darboux, 1899), *Eteone pacifica* Hartman, 1936, *Nereis vexillosa* Grube, 1851, *Ctenodrilus serratus* (Schmidt, 1857), *Pherusa capulata* (Moore, 1909), *Armandia bioculata* Hartman, 1938, an unidentified oligochaete, the amphipods *Caprella californica* Stimpson, 1857, *Corophium acherusicum* (Costa, 1857), the pelecypod *Septifer bifurcatus* (Conrad, 1837), a chiton, *Mopalia sp.*, and the ectoproct *Bugula neritina* (Linnaeus, 1758).

Of the total number of macroscopic organisms collected from the *Mytilus californianus* community at the two marinas, 31, or 62%, were species in common; these species are indicated by an asterisk (*) in Table 1. Five species, the alga *Enteromorpha minima* Naegeli, 1849, unidentified specimens of isopods, amphipods, and pycnogonids, and one young specimen of the starfish *Pisaster ochraceus* (Brandt, 1835), were taken at Playa del Rey but not at Ventura County Marina.

DISCUSSION

The data obtained by Hewatt (1935) and these reported herein cannot be compared directly. The method of study differed. Hewatt removed a square yard (=8281 cm^2) of *Mytilus californianus* and associated organisms from an established community; observations were reported of the larger animals that settled in this scraped area for the ensuing year. He then revisited the area 1.5 years later and reported on the extent of the *M. californianus* and *Mitella polymerus* settlement. In the study on the new marina jetties collections were made shortly after the rocks were initially exposed to sea water, and the collections were always from a different but nearby position.

Hewatt summarized his data by stating that succession in the *Mytilus californianus* community seemed to progress as: (1) formation of an algae film, (2) appearance of algae feeders, (3) mussels and barnacles attach during their respective spawning seasons, (4) as the attached forms grow, the algae feeders are crowded to higher zones. The data reported herein differ from those of Hewatt. Algae were the first macroscopic inhabitants as Hewatt observed. *Mytilus californianus* settled within three months after initial exposure and continued to dominate the entire community until the entire association disappeared two years later. Limpets did not appear until after the appearance of *M. californianus* and the specimens collected were small until a year later. The elimination of *Ulva dactylifera* was largely completed prior to the appearance of algae feeders such as gastropods. The acorn barnacles, *Balanus crenatus* and *Chthamalus dalli,* did not appear in large numbers until the second summer; the majority of these specimens attached to the shells of the mussels rather than to the rocks.

The importance of the time of year rather than true succession for the pattern of development of the *Mytilus californianus* community is similar to the observations on the establishment of the *M. edulis* community in protected waters (Reish, 1964a). *Mytilus californianus* settled during the spring months shortly after the rocks were first exposed to sea water at both Ventura and Playa del Rey Marinas. The California mussel did not settle on rocks initially exposed to sea water in late summer until the following spring.

The growth rate of 6 mm per month is slightly less than the 7 mm per month observed by Coe & Fox (1942) for the same species at La Jolla, California. They found the principal growth in shell length to occur during the months when the water was colder with little or no growth occurring when the water temperature exceeded 20° C. Growth, as measured by the maximum size attained by a member of the population, occurred from the probable initial settlement in March to June and again during the following winter months.

The seasonal variation in the number of associated species is similar to that observed in the *Mytilus edulis* community on the floats in Alamitos Bay (Reish, 1964b). While water temperatures were not taken at Ventura County Marina, the seasonal difference in the population of associated organisms is presumed related to this factor.

No explanation is advanced to account for the elimination of the *Mytilus californianus* community from Site 1 at Ventura County Marina. The habitat of this mussel is described as being very common especially along the more exposed coasts of the intertidal zone (Soot-Ryen, 1955), although it is known to form beds in subtidal waters (Berry, 1954). *Mytilus californianus* is present at the end of the jetty and all along the outer side. No specimens of *M. californianus* have been observed on the north jetty; however, a sandy beach extends almost to the end on the ocean side of the jetty, probably eliminating any suitable environment for the mussel.

Typically, *Mytilus californianus* is known from the rocky shores and *M. edulis* from the bay environment. Specimens of both species may occur together; for example, Fitch (1953) reported both species attached to off-shore pilings of southern California. The rock jetties at the entrance of Playa del Rey Marina have overlapping populations (Figure 2). Two notable differences between the population of *M. californianus* at the two marinas were the smaller sized specimens (a maximum of 53 to 70 mm) and the larger number of specimens (a maximum

of 2261 to 1535) at Playa del Rey Marina. However, the total weight of the population of *M. californianus* was greater at Ventura County Marina. The rock jetties at Alamitos Bay and Newport Bay have a population of *M. californianus* at the end of the jetty and a population of *M. edulis* at the base of the jetty with an intermediate region in which neither mussel occurs.

SUMMARY

1. In a study of the growth and development of the *Mytilus californianus* community on rock jetties, newly constructed in Ventura County and Playa del Rey Marinas, data collected periodically over a two-year period indicated that *Ulva dactylifera* was the earliest macroscopic inhabitant regardless of what time of year the area was initially exposed to sea water. *Mytilus californianus* settled on the rocks during the spring months.

2. The larger, more diverse populations were encountered during the summer months and smaller, less diverse populations observed during the winter months.

3. The population of *Mytilus californianus* disappeared at Ventura County Marina after two years, but not at Playa del Rey Marina. No explanation is advanced at this time for this difference.

LITERATURE CITED

Berry, Samuel Stillman

1954. On the supposed stenobathic habitat of the California sea mussel. Calif. Fish and Game 40: 69 - 73

Bokenham, N. A. H., & T. Stephenson

1938. The colonization of denuded surface in the intertidal region of the Cape peninsula. Ann. Natal Mus: 9: 47 - 81

Coe, Wesley R., & Denis L. Fox

1942. Biology of the California sea mussel (*Mytilus californianus*). I. Influence of temperature, food supply, sex and age on the rate of growth. Journ. Exper. Zool. 90: 1 - 30

Fitch, John E.

1953. Common marine bivalves of California. Calif. Dept. Fish and Game, Fish Bull. 90: 102 pp.

Hewatt, Willis G.

1935. Ecological succession in the *Mytilus californianus* habitat as observed in Monterey Bay, California. Ecology 16: 244 to 251

Hoshiai, Takao

1960. Synecological study on intertidal communities. III. An analysis of interrelation among sedentary organisms on the artificially denuded rock surface. Bull. Mar. Biol. Sta. Asamushi, Tokoku Univ. 10: 49 - 56

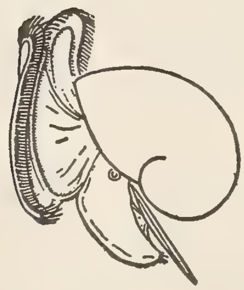
Reish, Donald J.

1964 a. Studies on the *Mytilus edulis* community in Alamitos Bay, California. I. Development and destruction of the community. The Veliger 6 (3): 124 - 131 (1 Jan. 1964)
California: II. Composition and variation of the associated

1964 b. Studies on the *Mytilus edulis* community in Alamitos Bay, organisms. The Veliger 6 (4): 202 - 207 (1 April 1964)

Soot-Ryen, Tron

1955. A report of the family Mytilidae (Pelecypoda). Allan Hancock Pacific Exped., 20, 1 - 175



A New Species of *Primovula* from the Philippines

(Mollusca: Gastropoda)

BY

CRAWFORD N. CATE

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(Plate 19)

CARIGARA BAY, SAMAR ISLAND in the Philippines is an area exceptionally rich in molluscan species of all kinds; notable among the less common *Cypraea* from this bay are *Cypraea pulchella* SWAINSON, 1823, *C. saulae* GASKOIN, 1843, and *C. pyriformis* GRAY, 1824, to mention only a few. During April 1962, commercial prawn and fish trawlers were working the ocean bottom in Carigara Bay in from 20 to 30 fathoms on a muddy substrate. Among the many hauls made on that particular trip, the fishermen brought up the above-mentioned cypraeid species and an unfamiliar example of the Ovulidae, which was sent to me for identification by Mr. Donald Dan of Manila.

After a thorough review of the material and monographs available to me (KIENER, 1843; SOWERBY, 1848; REEVE, 1865; WEINKAUFF, 1881; SCHILDER, 1932; ALLAN, 1956), and miscellaneous papers dealing with this group, I concluded that this species might be new to science. In order not to overlook any new species that might have been published subsequent to those works I had reviewed, I sent photographs of the new form to Dr. F. A. Schilder, who courteously compared them with specimens in his collection, ultimately verifying my suggestion that the shell in question was heretofore unknown. I wish to express here my appreciation for his kind consideration of the problem.

Primovula (Diminovula) dondani C. N. CATE, spec. nov.

Shell medium-sized, elongately ovate; aperture curving, narrow adapically, broadening but abruptly constricted in front; terminal ridge a continuation of the inflated base, straight, sharp, converging with inner fossular ridge; both front and rear terminals produced, adapically more so and narrower; first funiculum prominent, V-shaped, superimposed on base at abaxial margin of posterior columella; first posterior outlet separates the smaller second funiculum; terminal canals narrow, semi-enclosed; central transverse dorsal surface somewhat flattened, bordered on either side by a vague angular line; irregularly curved margin strongly developed, tubular, crossed by unevenly spaced, variously lengthened serrated teeth the entire length; terminal ridge straight, sharply ridged by eight weak serrated teeth; entire shell surface finely ridged with numerous transverse lines, crisscrossed laterally front to back with equally numerous very fine growth ridges; the body whorl is grey-white, darker on the base; the margins, teeth, terminals, terminal ridge, fossular ridge, and funiculum are white; interior of terminal canals very pale pink.

Primovula dondani is morphologically distinct from other known forms of Ovulidae; however, in several ways it seems related to shells of the subgenus *Prosimnia* SCHILDER, 1927. The ribs crossing the outer lip forming serrations are reminiscent of *Prosimnia coarctata* (ADAMS & REEVE, 1848), and of *Primovula mariae* SCHILDER, 1941, but the lack of a transverse carina on the dorsum precludes its possible affinity with either of these species. It should be further pointed out that there is some similarity to *P. mariae* because of the denticles on the front terminal ridge. Since the first funiculum exhibits no dental ribbing, morphological evidence seems to ally this new species with *Primovula rhodia* (A. ADAMS, 1854). Another comparable species appears to be *Primovula bullata* (ADAMS & REEVE, 1848). Comparing further, one can see reflected structural exaggerations of both subgenera *Prosimnia* and *Primovula*.

The measurements of the holotype, a unique specimen, are as follows: length, 23.0 mm, width, 11.6 mm, height, 10.0 mm.

The type locality is Carigara Bay, Samar, Philippines (11°20′ N. Lat., 124°40′ E. Long.). The holotype will be deposited in the Philippine National Museum and will bear the catalog number N. M. CO. 07287.

I have named this shell in honor of Donald Dan of Manila, who was the first to point out that this form might be new.

LITERATURE CITED

ALLAN, JOYCE

1956. Cowry shells of world seas. Georgian House, Melbourne. i - x; pp. 1 - 170; plts. 1 - 15

Figure 1 Figure 2

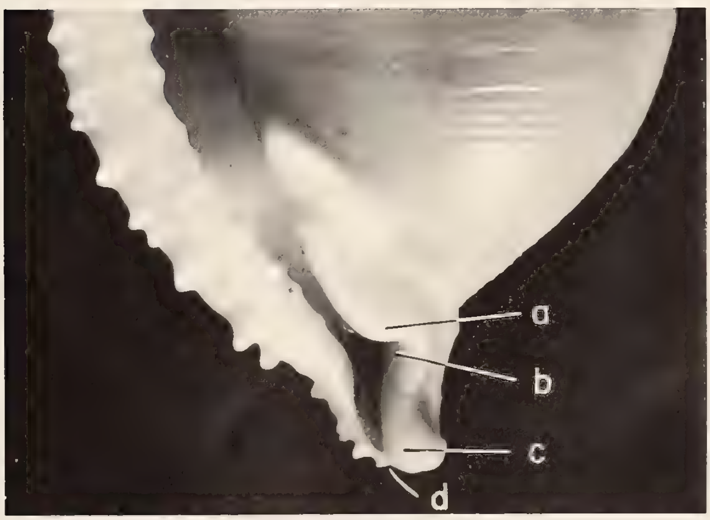

Figure 3

Figures 1 and 2: Dorsal and Ventral Aspects of
Primovula (*Diminovula*) *dondani* C. N. CATE, spec. nov. (x $2\frac{1}{4}$)
Figure 3: Enlarged View Showing Detail of Posterior End of Shell (x 7)

a: first funiculum d: second posterior outlet
b: first posterior outlet c: second funiculum

photo. Takeo Susuki

KIENER, L. C.

1843. Spécies général et iconographie des coquilles vivantes. Genre Ovule; pp. 1 - 16; plts. 1 - 6

REEVE, LOVELL AUGUSTUS

1865. Conchologia Iconica; monograph of the genus *Ovulum;* plts. 1 - 14

SCHILDER, FRANZ ALFRED

1932. The living species of Amphiperatinae. Proc. Malac. Soc. London, 20: 46 - 64; plts. 3 - 5

SOWERBY, GEORGE BRETTINGHAM

1848. Thesaurus Conchyliorum, or monographs of genera of shells. London. *Ovulum.* 2: 467 - 484; plts. 99 - 101

WEINKAUFF, H. C.

1881. Die Gattungen *Cypraea* und *Ovula.* Conchylien-Cabinet (2nd. ed.), MARTINI & CHEMNITZ. Nürnberg, pp. 1 to 230; plts. 1 - 53A

The Cowries Established by COEN in 1949

(Mollusca: Gastropoda)

BY

FRANZ ALFRED SCHILDER

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GIORGIO SILVIO COEN (1949) has described many "new varieties" and two "new species" of cowries; his paper has been quoted in the Zoological Record (86:74-76), but the periodical in which it has been published is hardly available in public libraries so that even ALLAN (1956: 114) must admit that COEN's publication is unavailable to her. After several vain attempts to get a copy of the paper, I asked Mr. S. P. DANCE, British Museum, for a photocopy for which I am much obliged to him. It proved that both in the Zoological Record and in the list given by ALLAN (1956: 114-115) some new names have been omitted or incorrectly spelled.

With only one exception *(Erosaria erosa pulchella* COEN, 1949) the many new names established by COEN are of no scientific value, as they refer to individual varieties or even monstrosities, the exact habitat of which is often unknown or even incorrect; several varieties evidently belong to other species than COEN thought. Nevertheless these names have been established in a valid trinominal way, so that they must be considered in all future synonymic lists. Many names, however, would become invalid by secondary homonymy if one would lump all cowries to one monster genus *Cypraea* as recently several malacologists are doing, whereas COEN followed the "splitters" and adopted many natural genera.

Therefore I think it useful to publish an excerpt of COEN's descriptions for the great number of malacologists who cannot obtain the original publication written in Italian. Moreover, I have added my own interpretations of the varieties established by COEN, which have been always put in [square brackets] so that they can be well distinguished from COEN's indications. My remarks also include the results of personal examination of type specimens (preserved in COEN's collection) during my visits to Venice in 1931 and 1933; most type specimens, however, seem to have been acquired by him in later years. I have been told by COEN's widow that his collection has been located at Tel Aviv (Israel).

COEN's descriptions are very short, and in the following review they have been still more restricted to the essential characters distinguishing the "new varieties" from usual specimens. COEN indicated the length and the maximum breadth of the holotype in mm, but in this review I have expressed the breadth in per cent of the length, separated from the length (in mm) by the sign /. I should like to call the attention of readers of the original publication to the curious fact, that COEN evidently used the terms "right" and "left" in an unusual way so that the outer lip which is the right margin of the creeping mollusk is called "left" if the shell is regarded from the dorsal aspect, e.g. p. 14:

Erosaria erosa pulchella, p. 15: *E. caputdraconis punctatissima* (the dorsal line is always placed above the right margin!), p. 17: *Erronea errones fusca* ("on the lip and the right side"); but it is correctly called "right" by basa view (e.g. *Erronea caurica caledonica).*

Coen indicated type localities of all new varieties; many indications, however, are practically worthless, as they refer to world wide regions only; he often added "s.l." (senza località=without [exact]locality). Other localities marked by Coen with the sign ! (which has also been adopted in the present review) are said to be "exact and sure".

Coen's arrangement of genera and species has been adopted in this paper.

The following cowries have been named and described by Coen (1949):

(Coen, page 13)

Cypraea (Vulgusella) tigris fuscoapicata: 81/75 and 68/71, extremities dorsally dark brown, dorsal spots confluent longitudinally [not fully grown abnormity]; Australia s.l. [habitat uncertain].

Cypraea (Lyncina) lynx nigroguttata: 33/68, subcylindrical, margins thickened, lateral spots tuberculate [extremely callous abnormity]; Indian Ocean [no habitat].

Cypraea (Lyncina) lynx javana: 32/66, margins heavily callous [widely spread common variety]; South coast of Java!

Cypraea (Lyncina) vitellus gibbosa [name preoccupied]: 43/72, gibbous and callous [frequent variety]; Guam!

Cypraea (Lyncina) carneola pretiosa [name preoccupied]: 22.5/64, small, glossy, otherwise typical [the smallest known *C. carneola* Linnaeus, 1758, is 17.2 mm long]: Benadir! [in formerly Italian Somaliland].

Cypraea (Lyncina) carneola aurea [name preoccupied]: 39/59, pale yellow without dorsal zones, teeth whitish, like in *loebbeckeana* Weinkauff, 1881 [of which *aurea* becomes a synonym]; Australia [doubtful].

Mauritia (Arabica) arabica dilatata: 55/76, anterior extremity dilated, inner lip swollen, thus recalling *maculifera* Schilder, 1932, but without basal blotch [callous variety]; China Sea! [Coen presented me a paratype (coll. Schilder 4984) from "China" which word was written on the shell itself: 53/74 with 30:26 teeth, margins much expanded, base flattened, dorsum lineate longitudinally without distinct lacunae.]

(Coen 1949 p. 14)

Mauritia (Arabica) arabica gibba: 52/67, humped as [*Trona*] *stercoraria* Linnaeus, base swollen; China Sea! [The holotype very probably came from the same population as *dilatata* Coen; it is an inflated callous *arabica* (Linnaeus 1758).]

Mauritia (Arabica) eglantina aurea: 46/57, yellow like gold, dorsal markings hardly visible, the spire blotch excepted [more probably suffused by yellow enamel than a pellucid variety; besides such shells can be obtained artificially by exposing usual shells to dry heat of 100° Centigrade for one day]; Indian Ocean s.l. [no habitat].

Mauritia (Arabica) eglantina rufa: 66/59, throughout reddish brown, dorsally adorned with usual markings, base white [evidently an abnormity suffused with chestnut]; Indian Ocean s.l. [no habitat].

Mauritia (Arabica) histrio duploreticulata: 85/65, the two uppermost layers of the dorsal reticulate enamel do not cover each other exactly so that the whitish lacunae become crossed by brown lines [frequent abnormity with the uppermost dorsal layer displaced]; Indian Ocean s.l. [no habitat].

Luria lurida onycina: 23/57 from Palermo!, and 27/63 from Tunis! (both ex coll. Monterosato): small, olivaceous, inzonate though glossy [frequent variety].

Luria lurida incrassata: 34/71, gibbous, callous, inzonate [variety frequent in surf localities]; Tyrrhenian Sea [inaccurate indication].

Luria lurida badia: 36/58 and 21/62, brown, inzonate [frequent variety]; Sicily! [The smaller paratype has been presented to the writer (coll. Schilder 4988), it is 20.6/62 with 12:14 teeth, greyish brown, inzonate though being collected alive; four other shells in coll. Coen vary from 21 to 23.5 mm; the smallest known Mediterranean *lurida* (Linnaeus, 1758) is 14.3 mm long (coll. Schilder 1214).]

Luria lurida liburnica Coen, 1937: not described, only with reference to Coen 1937, p. 150 [though it has been established first by Coen 1933 p. 162 from Dalmatia]: 45/62, thin, zonate [the holotype in coll. Coen is a large pale *lurida*].

[The monstrosity *Luria lurida obstructa* Coen 1933 and 1937 has not been mentionel by its author in 1949.]

Luria (Basilitrona) isabella cylindroides: 25/46, cylindrical, dorsum with black striæ, extremities orange [it seems to be the narrowest specimen known, though Hawaiian *controversa* (Gray, 1824) sometimes shows a minimum index 47]; Fiji! (*ex coll.* Dautzenberg) [possibly erroneous, as Fijian *isabella* (Linnaeus, 1758) usually are much broader].

Monetaria moneta annulifera [name preoccupied]: 25/80, broad, lateral and six basal tubercles well developed, orange dorsal ring distinct; Indian Ocean s.l. [no habitat. The holotype in coll. Coen is 24.4/80, broad with lateral tubercles oblique as in ecotype "M" of Schilder 1937, p. 1122, dorsal ring vividly yellow, aperture straight, but bent behind, base with five right and two left prominent tubercles; a paratype from the same unknown locality (coll. Coen) is 20.5/72 with similar dorsal ring and lateral and basal tubercles, but with wider aperture; both shells seem to belong still to ecotype "R".]

Erosaria erosa marginata: 38/66, margins enormously thickened, outer lip crossed by the labial teeth, dorsal line replaced by a slight sulcus [extreme variety occurring in surf localities]; Red Sea! [wrong, as *erosa* (Linnaeus, 1758) does not live in the Red Sea].

Erosaria erosa pulchella: 18/58 with 13:12 teeth only [which is about the average closeness of teeth in *erosa* (LINNAEUS, 1758)], pale, left [=right] lateral blotch absent, base white. Australia! [This name could be adopted for the local race of New South Wales characterized by the absence of the labial lateral blotch (see SCHILDER 1963).]

Erosaria diaphana n.sp.: allied to *erosa* [LINNAEUS], 15.5/65, cylindrical, light, right margin pitted, hardly thickened, 11 produced labial and 12 short columellar teeth, pellucid, white, without any markings [evidently an albinism of *erosa* if not a bleached beach specimen]; Australia s.l. !

(COEN, p. 15)

Erosaria lamarcki inocellata [name preoccupied]: dorsal spots pure white; Benadir! [formerly Italian Somaliland]. [Unfortunately COEN did not indicate the dimensions of the holotype, as the markings are comparable to the dwarf race from Port Reitz, Kenya (SCHILDER, SCHILDER & BENTON 1962).]

Erosaria ocellata fasciomaculata: 28/64, dorsum with a transversal zone and white points, bordered with two large square brown blotches above the margins. Red Sea! [According to the description and the habitat *(ocellata* (LINNAEUS, 1758) does not live in the Red Sea) the holotype must be a typical *Erosaria nebrites* (MELVILL, 1888); the chestnut basal striæ of *nebrites* (which was evidently unknown to COEN) misled COEN to think the shell to belong to *ocellata*.]

Erosaria acicularis nitidiuscula: 30/73, light, dorsum unspotted but slightly freckled with very pale yellow, dorsal line impressed [the markings of *acicularis* (GMELIN, 1791) are rather variable]; Antilles. [The holotype in coll. COEN is an *acicularis* of 30.1 mm, evidently suffused with whitish enamel.]

Erosaria helvola immaculata: 21/76, dorsum white, brown spots obsolete, lateral bands conspicuous [frequent variety in which the predominant white specks coalesce]; [formerly Italian] Somaliland!

Erosaria spurca peculiaris: 33/55, elongate, dorsum whitish with minute brown spots [frequent variety]; Libya! and Sicily!

Erosaria spurca inflata: 32/66, globose, spire acuminate, inner lip acutely protruding beyond the outer lip posteriorly; [a monstrosity] as COEN himself has presumed; Taormina! [in Sicily].

Erosaria (Ravitrona) caputserpentis albosignata: 30/77, with the dorsal spots partially confluent to large white blotches united with the dorsal line [abnormal aberration]; India [practically no habitat].

Erosaria (Ravitrona) caputdraconis punctatissima: 26/69, dorsal area reddish brown with fine white points, contrasting with the dark margins, but separated by the pale dorsal line above the left [= right] margin [insignificant aberration]; Easter Island !

Staphylaea staphylaea fortis: 21/67, solid, dorsal tubercles coarse, color rather typical [frequent variety]; Polynesia s.l. [no habitat].

Staphylaea staphylaea nitida: 15/60, dorsum smooth, but central line impressed, milky white, extremities orange, teeth yellowish [probably not fully grown and bleached]; Australia s.l. [possibly correct].

Staphylaea staphylaea consobrina lactea: 19/63, white, extremities and teeth orange [such shells mostly are bleached]; Batavia! [= Djakarta].

Staphylaea staphylaea consobrina grisea: 18/61, granulate, grey, extremities dark brown, base white [probably subjunior]; Polynesia [no habitat].

[The quadrinominal classification of the two last named *Staphylaea* contrary to all other strictly trinominal designations is surprising: I suppose that COEN intended to separate specifically *consobrina* (GARRETT, 1879), from *staphylaea* (LINNAEUS, 1758) and forgot to erase the latter name used in the two paragraphs before.]

Staphylaea limacina ebur: 25/56, smooth, glossy, ivory white, unspotted; Hawaii ! [Such pale shells have been found in Hawaii in subfossil state, but they belong to *Staphylaea semiplota polita* (ROBERTS, 1868), whereas *St. limacina* (LAMARCK, 1810) does not live in Hawaii; therefore *ebur* should be removed to *semiplota* (MIGHELS, 1845).]

Staphylaea limacina nitens: 24/58, smooth, ivory white with white dots, extremities and teeth orange; Oceania s.l. [no habitat; such pale shells occur both in *limacina* and *semiplota*, but I suspect *nitens* to belong to the latter and to come also from Hawaii, as *limacina* is restricted to the south-western and western borders of "Oceania" only].

(COEN, p. 16)

Nuclearia nucleus cerea [name preoccupied]: 24/67, wax-colored without red lines anywhere [pellucid or bleached]; Madagascar ! [The name *cerea* has been used by PAETEL 1887 for an undescribed variety (nomen nudum), of *nucleus* (LINNAEUS, 1758) but adopted by SULLIOTI 1924 for the albinistic *nucleus*.]

Pustularia cicercula purissima: 20/62, glossy, tuberculate, pure white; Mauritius ! (ex coll. MONTEROSATO ex coll. GERET). [Such subpellucid *cicercula liénardi* (JOUSSEAUME, 1874) occur in Mauritius.]

Luponia fuscodentata alba: 32/66, slightly worn, pure white [such bleached shells will be found sometimes

among beach specimens]; Cape of Good Hope ! [probably from the South coast east of the Cape itself].

Notocypraea angustata lentiginosa: 22.1/70, solid, margined, flesh colored, minutely freckled with brown [as *angustata* (GMELIN, 1791) is always unspotted, this description exactly fits *Notocypraea declivis* (SOWERBY, 1870) of which *lentiginosa* becomes a synonym]; Tasmania!

Guttacypraea pulicaria candida: 15.5/39 [such extreme slenderness is very improbable so that I suspect an error in measuring], hyaline, white, unspotted [albinistic or bleached]; West Australia.

Zonaria pyrum elongata: 31/58, more elongate than typical *pyrum* [(GMELIN, 1791), but within the usual range of variation as I know shells down to the index of breadth 53]; Naples !

Zonaria pyrum cruenta: [no dimensions indicated] base blood red [well known extreme color variety]; Naples ! [The holotype in coll. COEN is 35.8 mm long, very dark, with distinct dorsal zones.]

Zonaria pyrum confusa: [no dimensions indicated] dorsum confusely spotted, zones invisible, base fulvous [a frequent variety]; Tyrrhenian Sea and Dalmatia!

Zonaria pyrum hepatica: 39/59, base liver-brown [a frequent variety]; Naples!

Zonaria pyrum piperitoides: 28/64, pale, zones interrupted as in the variety *undata* PALLARY so that the shell recalls *Notocypraea piperita* var. 1 of HIDALGO [1907; the latter is *Notocypraea bicolor* (GASKOIN, 1849); COEN's shell represents a frequent abnormity, probably not fully grown] Naples!

Zonaria pyrum compressa: 33/61, outer lip compressed in its central part [pathological monstrosity]; Tyrrhenian Sea [inaccurate indication].

Zonaria pyrum nivosa: 37/59, small [the mean of *Z. pyrum* (GMELIN, 1791) is 35 mm], dorsum with two white bands and two irregular white blotches on the rear, base yellowish [abnormity]; Linosa! [holotype] and Lampedusa ! [paratype in coll. COEN: 31.9 mm, saturate, with three dark zones and round light lacunæ on the dorsum: a frequent variety].

Zonaria pyrum aurantia: 35/63, dorsum with three white bands, base vividly orange [common variety]; Mediterranean Sea [no habitat].

Zonaria pyrum minima (MONTEROSATO MS.); 24/54, the smallest known specimen, otherwise typical; Viareggio! (ex coll. MONTEROSATO). [The holotype in coll. COEN is 23.8 mm long, rather saturate, with the dark central zone indistinctly divided into two parts. MONTEROSATO 1897 has published a var. *minor* of 26 mm; I have seen a *Z. pyrum* of 22.5 mm only from Tunis in coll. DAUTZENBERG].

(COEN, p. 17)

Zonaria pyrum physoides: reference to COEN 1937 only [though established already in COEN 1933 (see above sub *Luria lurida liburnica*); in this paper it is described as 42/62, recalling *Schilderia achatidea* (SOWERBY 1837), var. 2 of HIDALGO 1907 in color, but differing in dentition; Dalmatia. The holotype in coll. COEN is a rather young, pale *Z. pyrum* (GMELIN, 1791) with pale fulvous base; specimens from Dalmatia usually are larger than from elsewhere].

Erronea errones fusca: 24/60, not fully grown, outer lip shortened in front, dorsum leaden-colored, trizonate, base whitish [a young shell, deformed pathologically]; Cape St. Jacques in Cochinchina!

Erronea caurica immaculata: 55/53, oblong, rather pale, dorsal blotch absent [common variety]; Benadir! [formerly Italian Somaliland. The holotype in coll. COEN is a subpellucid variety of *caurica* (LINNAEUS, 1758).]

Erronea caurica multidentata: 46/55, with 26 labial and 24 columellar teeth, otherwise similar to the preceding [the closeness of teeth is about at the border of the known range of variation]; Red Sea !

Erronea caurica nitens: 36/53, oblong, vitreous, dorsal zones and specks rosy, lateral spots reddish, base pale flesh color [typical pellucid variety]; Mauritius! [The holotype in coll. COEN belongs to the pellucid variety rather frequently collected in Mauritius.]

Erronea caurica caledonica: 25/60, right margin thickened and spotted, the brown lateral blotches are absent [a curious remark by COEN as *erosa*-like blotches never occur in *caurica*], dorsum trizonate and freckled with fulvous, base white [a typical *caurica*(LINNAEUS, 1758)]; New Caledonia !

Erronea pseudarabicula n.sp.: allied to *caurica,* 23/61, with 15 teeth on each lip [closeness approaching the mean of *caurica*], shape as in *caurica,* but color as in *Pseudozonaria arabicula* (LAMARCK, 1810): dorsum bluish, with chestnut specks coalescent in three transversal zones, right lateral spots confluent to a longitudinal band [as in var. *nigrocincta* SCHILDER, 1924], base flesh color; [formerly Italian] Somaliland! [There is no reason to separate this slight aberration of *caurica* (LINNAEUS, 1758) as a new species.]

Blasicrura cylindrica emaculata: 31/48, typical, but without the usual dorsal blotch [which may disappear gradually as in other *Erronea*]; Australia [possibly correct].

Palmadusta asellus fusca: 18/56, dorsum fulvous [instead of white] between the dark zones, but margins white [an aberration occurring sporadically]; Red Sea ! [locality doubtful, as the only indications by ISSEL 1869 and SMITH 1903 seem not to be reliable].

Palmadusta diluculum magnifica: 28/63, dorsum covered with fine transversal lines except in the central zone where they are replaced by a row of arrow-shaped white spots [the long description refers to a shell in which the two dark central zones are reduced so that the zigzag lines become predominant]; Zanzibar !

Palmadusta diluculum epunctata: 21/62, dorsum with three rows of yellowish red blotches, the intermediate bands are plain white, lateral and terminal black spots absent [the frequent pellucid variety of *diluculum* (Reeve, 1845); the unspotted margins point to the Lemurian race *virginalis* Schilder & Schilder, 1938]; Philippines [erroneous, as *diluculum* is restricted to the western Indian Ocean; the incorrect habitat Philippines indicated by Reeve (1845) has been copied by many collectors and dealers].

Palmadusta (Purpuradusta) fimbriata nitida: 17.5/63, dorsum white, plain or with minute brown specks [Coen evidently had in mind *gracilis* (Gaskoin, 1849) which has been incorrectly called *fimbriata* (Gmelin, 1791) by writers prior to 1938; a paratype from the Persian Gulf presented to me by Coen (coll. Schilder 4987) is a *P. gracilis:* 17/62, with 17:16 teeth, ovate, rather callous, suffused with a thin layer of white enamel, so that the pink tips and brownish lateral dots become very pale; other specimens in coll. Coen (including the holotype) were still more suffused with white]; Persian Gulf!

Siphocypraea mus suta: 35/71, dorsal area with grey zigzag lines [characterizing young specimens], accompanied at the left [=right] margin by one longitudinal series of blackish spots from anterior extremity to the spire blotch, recalling roughly a stitched suture [latin *suere* = stitch; I possess a similar individual aberration]; Antilles! (ex coll. Cuming).

(Coen, p. 18)

Primovula carnea gibbosa: [no dimensions indicated], dorsum asymmetrically gibbous on the left side [pathological monstrosity]; Trapani! and Dalmatia! [see below].

Primovula carnea dorsolirata: 12.5/56, pinkish, dorsum with 10 to 12 white longitudinal ribs [another monstrosity], Capri Island!

Primovula carnea major: 19.5/59, thin, white, approaching *Primovula adriatica* (Sowerby, 1828). Ancona! and Lesina! [Probably a synonym of *adriatica,* as *carnea* (Poiret, 1789) does not seem to have been reported from the Adriatic Sea before Coen 1949; Coen did not indicate the differences of *major* from *adriatica.*]

Simnia (Neosimnia) spelta brevis: 13.1/57, shorter and more convex, pale flesh color [insignificant aberration]; Palermo! (ex coll. Monterosato).

Simnia (Neosimnia) spelta illyrica [name preoccupied]: 11.5/52, elongate, with the rear produced, wax-colored, Dalmatia! [It is a synonym of *Simnia (Neosimnia) illyrica* Schilder, 1927 from the Adriatic Sea: a curious case of independent identical naming of the same variety by two authors.]

Jenneria pustulata bimaculata: 18/72, with a dark brown blotch at each end of the dorsal sulcus [these blotches are well visible in most fresh specimens, but they become often rather pale and indistinct]; Panama!

Jenneria pustulata pumilio: 11/64, extremities whitish dorsally, otherwise typical [the museum of Hamburg, destroyed during World War II, possessed several specimens of 11 mm, the smallest measuring 10.3 mm; they came from Diego]; Panama!

Trivia dalmatica Coen 1937: reference only [The shell described by Coen 1937 p. 150 evidently is a *Trivia multilirata* (Sowerby, 1870), measuring 11.4/79; in 1933 Coen possessed several specimens from the Adriatic Sea, varying from 7.8 to 14.7 mm; a paratype presented to me (coll. Schilder 3361) is 9.8/78 with 25:21 teeth and 68 ribs around the shell].

LITERATURE CITED

Allan, Joyce

1956. Cowry shells of world seas. Georgian House, Melbourne. i-x; pp. 1-170: plts. 1-15.

Coen, Giorgio Silvio

1933. Sylloge molluscorum adraticorum. Mem. R. Comit. Talassogr. Italiano. 192: 46-47, 162; plt. 3

1937. Nuovo saggio sylloge molluscorum adriaticorum. Mem. R. Comit. Talassogr. Italiano, 240: 46 to 47, 150 to 151, 162

1949. Nota su alcune forme nuove di "Cypraeacea." Hist. Nat. Roma 3 (1): 13 to 18

Schilder, Franz Alfred, & Maria Schilder

1937. Revision of the genus *Monetaria* (Cypraeidae). Proc. Zool. Soc. London, 1936 (4): 1113-1135; plts. 1-2

1963. Studies in variation of cowries: The marginal blotches of *Erosaria erosa* (Linnaeus). Hawaiian Shell News, n. s., 43: 4-5

Schilder, F. A., Maria Schilder, & Ronald Stewart Benton

1962. Studies on *Erosaria lamarckii* Gray (Gastropoda). The Veliger 5 (1): 30-32 (1 July 1962)

Zoological Record, London

1952. volume 86 (for 1949): 74-76

A New Species of the Lamellibranch Genus *Aligena* from Western Canada

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(Plate 20)

THE WEST AMERICAN REPRESENTATIVES of the Leptonid genus *Aligena* were reviewed by BURCH (Nautilus **55**: 48-51) in 1941. At that time he described *Aligena redondoensis*. This was the fourth described West American species and the only one known to occur north of Baja California. It is reported from the regions off La Jolla, off Santa Rosa Island and from the submarine canyon off Redondo Beach, Calif.

On May 18, 1963, I and others were dredging in the northern parts of the Strait of Georgia, Johnston Strait and adjacent waters. At Cowan Station 724, 49° 15′ north and 124° 15′ west in 190 fathoms we took a number of specimens of a Leptonid new to me. I am indebted to Dr. Myra Keen of Stanford University for assistance with the identification, for suggestions as to the systematic affinities and for critical reading of this manuscript. The specimens secured represent an undescribed species that approaches the genus *Aligena* more closely than it does other described genera. It differs significantly from all other members of the genus in the consistent possession of a prominent lateral tooth. In as much as inclusion of the new species in *Aligena* will necessitate some revision in the generic diagnosis, the question arises as to whether the creation of a new genus would not best describe the situation. In a less variable family this would probably be the action of choice. In the present instance, however, it has been decided to leave final decision on this to a future reviser of the family. However, a new subgenus under *Aligena* is required to express the apparent relationships among the 6 species.

I propose the name ***Odontogena*** with the type species *Aligena (Odontogena) borealis* Cowan.

Diagnosis: Differs from *Aligena (Aligena)* primarily in having a well developed posterior lateral tooth on each valve. The detailed description, type locality and other details are given below in the species description.

The new species was collected in a Naturalist dredge with ⅛ inch nylon liner in the net. The substrate consisted of very soft, fine-textured muddy silt. Its faunal associates were *Yoldia martyria, Cardiomya planetica,* and *Pandora filosa*. The new species must be very local in its distribution as several hundred dredge hauls in the Strait of Georgia have failed to reveal it. Six hauls were made in the general vicinity of the type locality yet the species was taken only in the one place.

Aligena (Odontogena) borealis COWAN sp. nov.

Type locality: The northern part of Georgia Strait, British Columbia, Canada, at 49° 15′ North latitude and 124° 15′ West longitude. Depth 190 fathoms at Cowan Station 724.

Type specimens: The holotype has been deposited in the Stanford University Paleontology Type Collection as No. 9739 along with paratypes 9740-9741; paratype 4762 D is in the United States National Museum; 4762 E in the Museum of Comparative Zoology, Harvard University; 4762 F in the National Museum of Canada; 4762 G in the British Museum of Natural History; 4762 H in the California Academy of Sciences. The remaining 7 specimens of the paratype series of 4762 are in the Cowan collection.

Description: The details given describe the entire series, not merely the holotype. A small almost circular shell with a mean length of 2.50 mm, mean height of 2.31 mm, and mean ratio of height to length of 0.92. Moderately inflated, ratio length to thickness 0.58. Almost symmetrical, beaks central, prominent and bent forward to leave a well developed depression in front of and beneath the beaks. This is not, however, differentiated as a lunule.

Anterior margin curving in an even arc into the ventral margin. Dorso-posterior margin curved but inclining downwards at an angle of about 45 degrees from the plane of the anterior dorsal outline. Posterior margin with a small central prominence.

Shell pale yellowish, possibly as a stain from the heavy and complete coating of mud that adhered to every specimen. This flaked off easily when dry. Sculpture of incremental lines only (Figure 1). Hinge internal, behind

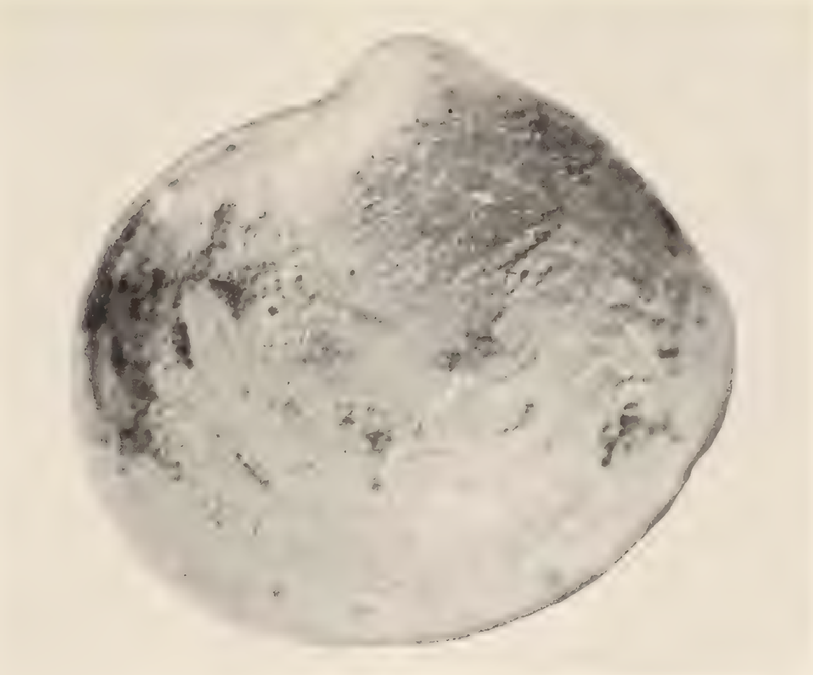


Figure 1: View of entire shell from left aspect.

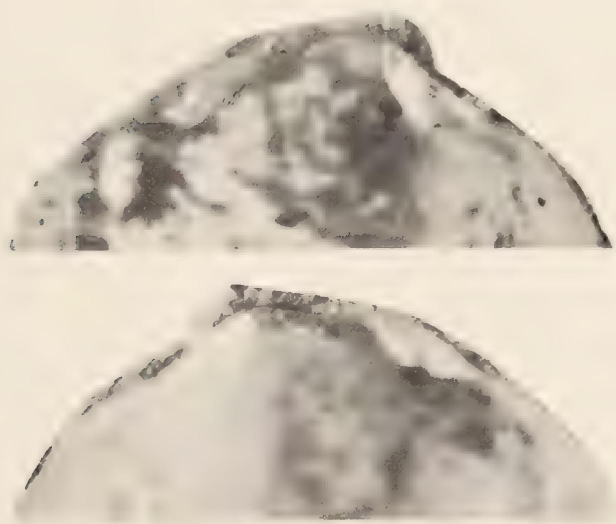


Figure 2: Upper - dentition of left valve.
Lower - dentition of right valve.

Measurements of type series of *Aligena borealis*

	length	height	thickness	ratio l/h
1.	2.64 mm	2.53 mm		.96
2.	2.64	2.31		.87
3.	2.53	2.20		.87
4.	2.64	2.20		.83
5.	2.64	2.31		.87
6.	2.64	2.42		.91
7.	2.53	2.31		.91
*8.	2.64	2.42	1.43	.91
9.	2.53	2.42	1.54	.96
10.	2.31	2.20	1.32	.96
11.	2.64	2.42	1.54	.91
12.	2.42	2.31	1.54	.95
13.	2.57	2.42	1.43	.94
14.	2.42	2.42	1.54	1.00
15.	2.42	2.20	1.32	.91
16.	2.20	2.20		1.00
17.	2.42	2.20		.91
18.	2.42	2.20	1.32	.91
19.	2.22	2.20	1.42	1.00
20.	2.42	2.20	1.54	.91
Mean:	2.50	2.31	1.45	.92

* 8 - 20 measured with mud adhering. Deduct 0.1 mm for cleaned dimensions.

umbos. Left valve with a long narrow chondrophore which may be recessed well beneath the hinge margin. Beneath and in front of the umbo is a heavy plate upon the ventral margin of which arises a thick tooth either as a ridge or a prominent cone (Figure 2). There is a deep sulcus between the tooth and the dorsal margin. A similar plate half way down the length of the postero-dorsal margin bears a deep sulcus and a prominent posterior lateral tooth. The teeth of the right valve consist of strong ridges that fit into the corresponding cardinal and posterior lateral sulci of the opposing valve.

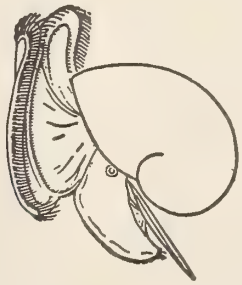
There is considerable variation in form of the teeth on the right valve. A frequent variant is with each tooth divided by a groove into two parts.

Comparison: *Aligena borealis* differs from *A. redondoensis* in its yellowish rather than white colour; in being almost perfectly symmetrical rather than with anterior end longer; in having the height-length index nearer to unity; in having the anterior extremity more rounded, umbones more prominent; cardinal tooth plate and tooth much heavier; and in the presence of the large posterior lateral tooth on both valves.

To bring the key to the genus *Aligena* up to date it is necessary only to insert an initial couplet separating the new species on the basis of its dentition as follows:—

1 Shell with prominent posterior lateral tooth on each valve . . . . *A. borealis*
—Shell without posterior lateral teeth 2
2 Shell with median radial constriction . . *A. cokeri*
—Shell without median radial constriction . . . 3
3 Anterior part of shell sloping abruptly down . . . . *A. cerritensis*
—Anterior part of shell not sloping abruptly down . 4
4 Posterior portion of shell sloping gently down, left valve with cardinal tooth . *A. nucea*
—Posterior portion of shell sloping abruptly down, left valve edentulous . . *A. redondoensis*

The new species extends the known range of the genus some 1,500 miles north of its previously known limit.



New Information on the Distribution of Marine Mollusca on the Coast of British Columbia

BY

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Through the last eight or ten years intensive investigation of the marine mollusca of the coast of British Columbia has led to the modification of the known range of many species. The investigations have not been evenly distributed. Regions collected in most detail have been the north coast of Graham Island and adjacent waters by Peter Henson of Masset, B.C., and the Strait of Georgia, Johnston Strait, Queen Charlotte Strait and the south west coast of Vancouver Island by the present author. Several other collectors have worked primarily in the Strait of Georgia, and Dr. D. B. Quayle and his associates have explored more widely. The majority of their collections, however, have not yet been worked up. Rae Baxter of Cordova, Alaska, made a canoe traverse of the coast collecting in the intertidal in which certain local range extensions were obtained.

I am indebted to all of these for permission to include their findings. I wish especially to acknowledge the generosity, assistance and companionship of Peter Henson whose enthusiasm has led to greatly increased knowledge of the mollusc fauna of the Queen Charlotte Islands area. He has given me permission to record certain major extensions of range represented by specimens in his collection but missing from mine. James McLean, of the Department of Biology, Stanford University and Dr. R. M. Rosenblatt of Scripps Institute accompanied me on some expeditions. Several malacologists have given advice and assistance on critical determinations. For this I am particularly grateful to Dr. Myra Keen, Dr. Geo. Hertlein, Dr. A. H. Rehder, Mr. Allyn Smith, Mr. James McLean and Mr. Spencer Thorpe.

My own collecting has involved some 200 stations on the B. C. coast of which 40 were intertidal, 115 in the subtidal down to 50 fathoms, 30 between 50 fathoms and 95 fathoms and 17 from 100 to 200 fathoms. A very limited amount of Scuba diving has been involved in the immediate subtidal area but for the most part dredges of several types have been used.

The purpose of this paper is to record major range extensions that arise from the collecting so far undertaken. Certain groups are not included, because critical comparison with type material has not yet been made. Notably these include the Turrid genera *Oenopota* and *Mangelia* and the Pyramidellid genera *Turbonilla* and *Odostomia*. These will be reported upon later.

It is pertinent to note that 7 of the extensions of range reported here are southward and 29 northward. Ten of the latter now exhibit an apparent discontinuity of several hundred miles. Further collecting along the coasts of Washington and Oregon is needed before it can be concluded that any of these species are divided into northern and southern centers of occurrence separated by an uninhabited area.

Lamellibranchia

Nuculana austini (Oldroyd, 1935) Previously known from the west coast of Vancouver Island, now extended north to Masset Inlet, Graham Island, Q. C. I.

Nuculana pernula (Müller, 1779) Several unusually large *Nuculana* from Chatham Sound, Q. C. I. at 30-60 fathoms are closest to this species though differing slightly from specimens originating in Arctic Canada. Not previously reported in the Pacific south of the Arctic Basin.

Yoldia martyria Dall, 1897. Although the published distribution of this species is from Kasa-an Bay, Alaska, to the Gulf of California. I have been unable to find specimens from the area north of the Olympic Peninsula, Washington, except for one in the U. S. N. M. This one, from Kasa-an Bay, is in poor condition and not identifiable with certainty. The species is common in 100+ fathoms on soft mud bottoms off the northern end of Texada Island, B. C., and I have a single specimen from Barkley Sound, Vancouver Island.

Adula californiensis (Philippi, 1847). The northernmost record is from Vancouver Island, B. C. (La Rocque). Henson has found a colony near Yakan Point on the north

coast of Graham Island, Q. C. I., from which I have taken specimens.

Musculus taylori (Dall, 1897) Previously known only from Victoria, B. C. I have taken specimens from Hotspring Island, Q. C. I., where it was nestling in coralline algae.

Astarte willetti Dall, 1917. Reported only from the type locality, Forrester Island, Alaska. I have taken specimens at three localities south to Goose Island Banks in Hecate Strait and Barkley Sound, Vancouver Island.

Lasaea cistula Keen, 1938. Has been reported from Ensenada, Mexico, to Punta Arena, California. I have specimens from Cape Sutil and from Roller Bay, Hope Island, both at the northern tip of Vancouver Island. I am grateful to Dr. Myra Keen for verifying the identification of these specimens.

Tellina bodegensis Hinds, 1844. A specimen from La Pas Bay, west coast of Graham Island, Q. C. I., (Henson coll.) extends the range northward from Esperanza Inlet, Vancouver Island, the previously known limit.

Protothaca tenerrima (Carpenter, 1856). The locality records are extended northward to Esperanza Inlet, west coast of Vancouver Island. It was previously known from a northern limit at Victoria and Puget Sound.

Xylophaga washingtona Bartsch, 1921. Abundant in wood detritus to 60± fathoms at least as far north as Esperanza Inlet, Vancouver Island.

Penitella conradi (Valenciennes, 1846). Not previously recorded north of the San Francisco area, California. A group of 40± *Haliotis kamtschatkana* collected at Esperanza Inlet by D. B. Quayle and me bore this species in the heavier parts of the shell. Twenty-two specimens of varied sizes were taken. Examinations of several hundred shells of this abalone from Tofino Inlet, Barkley Sound, Victoria, Strait of Georgia, Port Hardy and the Queen Charlotte Islands has not turned up a single infected individual. The region from Esperanza Inlet north to Cape Cook, Vancouver Island, has yielded specimens of two species of algae and another mollusc *(Bornia)* not known elsewhere on the coast north of central California. It is tempting to suggest that this region occasionally experiences invasion of an offshore water mass originating on the California coast and that this bears with it the larvae of marine organisms and spores of algae from the area of origin. There is evidence, however, that this species is established in the Esperanza region as several age classes are represented.

Bornia cf. B. retifera Dall, 1899. Abundant in the entrance of a small lagoon in Esperanza Inlet in association with an enteropneust. Not previously known north of central California.

Gastropoda

Lepeta caeca (Müller, 1776). This species was recorded by MacGinitie (1959) south in the Bering Sea to the Aleutian Islands. The known range can now be extended south to Vancouver Island on the basis of 4 specimens dredged off Cape James, Hope Island, in 20-50 fathoms, and another taken off Halkett Point, Gambier Island, B.C.

Calliostoma variegatum Carpenter, 1864. I have taken specimens north to Queen Charlotte Strait at depths between 20 and 90 fathoms. It was previously known north to Puget Sound.

Calliostoma platinum Dall, 1889. This species has been previously recorded from the Farallon Islands to San Diego, California. On August 10, 1961, Henson took a living specimen (height 25.5 mm) in a dredge operating between 99 and 101 fathoms off Wiah Point, Queen Charlotte Islands. Since then a second specimen has been obtained.

Homalopoma engbergi (Willett, 1929). The only locality of record is Olga, Washington. I have specimens from Skidegate, Q. C. I., and from Port Dick, Alaska. The latter were collected by Rae Baxter.

Homalopoma lacunatum (Carpenter, 1864). This species was described from Neah Bay, Washington, as a species of *Gibbula*. The present assignment follows the suggestion of James McLean. It has been taken by me at Skidegate, Q. C. I., B. C.

Opalia chacei Strong, 1937. Specimens from Queen Charlotte Strait extend the known range north from the previous northern limit at central Oregon. The status of this species as distinct from *O. wroblewskii* remains to be determined. Specimens apparently referable to both these are found together in the waters off northern and central British Columbia.

Epitonium greenlandicum (Perry, 1811). Known south to Wrangell, Alaska, specimens have been taken by Henson and myself off the north end of Graham Island, Q.C.I.

Epitonium catalinae Dall, 1908. This species was taken by Willett at Forrester Island, Alaska, but there have been no other records of occurrence north of California. I took one specimen on La Perouse Bank off Barkley Sound, V. I., at a depth of 38-40 fathoms.

Epitonium acrostephanus Dall, 1908. The same dredge haul that produced the *E. catalinae* contained a living adult specimen of *E. acrostephanus*. Oldroyd (1924) records the species from the California coast only but

Burch (1944) gives Puget Sound as a locality without a reference.

Crepidula adunca Sowerby, 1825. Previously reported north as far as southern Vancouver Island (Departure Bay). I have specimens from Hotspring Island, Q. C. I., B. C., and Henson has beach specimens from the north coast of Graham Island, Q. C. I. It was very common on *Calliostoma ligatum* dredged in 7 fathoms on Nahwitti Bar, at the northern extremity of Vancouver Island. Whiteaves (1880) records specimens from an unknown locality in the Queen Charlotte Islands but the record has been questionable.

Hipponix antiquatus Linnaeus, 1767. Specimens taken on Graham Island, Q. C. I., first by Henson and later by myself extend the range northward from Vancouver Island. This is probably the same species recorded by Whiteaves (1880) as *H. cranioides* Carpenter from an unknown locality in the Queen Charlotte Islands.

Lacuna variegata Carpenter, 1864. Previously known north from California to Neah Bay, Washington, now known from Port Alexander, Nigei Island, B. C., and from Dall Island (U. S. N. M.) and Drier Bay, (McLean) Alaska.

Trichotropis bicarinata Sowerby, 1825. This boreal species has been taken previously south to Icy Cape, Alaska. The Henson collection contains a specimen taken at 57 fathoms off Cape Edensaw, Queen Charlotte Islands.

Trichotropis borealis Broderip & Sowerby, 1829. The southern limit of the known range can now be extended south to Nitnat Lake on the West Coast of Vancouver Island on the basis of a specimen in my collection. Henson has taken a living specimen in a crab pot 4-5 miles off Tow Hill, Q. C. I., B. C.

Bittium challisae Bartsch, 1917. This is the common *Bittium* in water 7 to 60 fathoms from Georgia Strait north to the northern end of the Queen Charlotte Islands. Previously known only from Puget Sound. The use of this name is subject to revision when the complicated synonymy of the genus is reviewed.

Ocenebra atropurpurea Carpenter, 1919. Described from Puget Sound. Specimens were taken by J. McLean and myself at Roller Bay on Hope Island. This places the species in the waters of Queen Charlotte Strait.

Ocenebra sclera (Dall, 1919). This species has been taken at several localities north to the north coast of Graham Island, Q.C.I. Previously known north to the Puget Sound area.

Amphissa versicolor Dall, 1871. This species is known to occupy a range from the Oregon coast to Cerros Island, Lower California, except for Dawson's (1880) report from Queen Charlotte Islands. I have taken specimens from several localities around Vancouver Island and at Wiah Point, Graham Island, Q.C.I., thus confirming the earlier record.

Nassarius fossatus (Gould, 1849). The presently known northern limit is Vancouver Island. Henson and I have both taken specimens near Yakan Point, and at Wiah Point, Graham Island, Q.C.I.

Neptunea ithia (Dall, 1891). This species has been known only from the coast of California south of Monterey Bay. I have three specimens from La Perouse Bank off the mouth of Barkley Sound, Vancouver Island, B. C. They were taken at depths of 40-60 fathoms.

Fusinus harfordii (Stearns, 1871). This species was described and known only from Mendocino County, California. In 1963 a party of us, including R. Rosenblatt of Scripps Institute, J. McLean of Stanford, G. I. McT. Cowan and myself obtained living specimens by Scuba diving, and dead specimens by dredging at Bull Harbour on Hope Island, B. C. In addition McLean took specimens on a boulder beach in the *Phyllospadix* community at Boulder Bay, Hope Island.

"Ophiodermella" grippi (Dall, 1919). A single specimen identified as this species was dredged in 15 fathoms in Toquart Bay, Barkley Sound, Vancouver Island, B. C., and two others from the Strait of Georgia in depths of 23 and 120 fathoms. The northernmost previous occurrence is in the San Diego area of southern California.

Ophiodermella fancherae (Dall, 1903). A small species of *Ophiodermella* presently referred to this species has been taken at various points along the British Columbia coast north as far as Wiah Point, Graham Island, Q.C.I. It was first taken by Henson in 1960 and by myself in 1961.

Cylichna nucleola (Reeve, 1855). This has been known as a circumboreal species not occurring south of the Bering Strait. I dredged 2 specimens that appear to represent this species off Sarita, in Barkley Sound, Vancouver Island, B. C.

Diaphana cf. D. brunnea Dall, 1919. This species has been known only from Kodiak Island, Alaska. I have specimens from Tofino Inlet, on the west coast of Vancouver Island and from Plumper Sound in Georgia Strait.

Polyplacophora

Chaetopleura gemma Dall, 1879. Two specimens of this species from Pachena Bay, Vancouver Island, B. C., and three more from Hope Island on Queen Charlotte Strait, B. C., extend the known range northward from the Monterey area of California.

Mopalia phormix Berry, 1919. This species has been known from subtidal waters of the Monterey area of California. I have taken a single specimen in 50 fathoms off Hood Point, Bowen Island, B. C., and 3 from Sidney Channel, Georgia Strait, B. C., at 40± fathoms.

Hanleya hanleyi (Bean, 1844). The genus *Hanleya* has been known from the Pacific on the basis of a specimen from Plover Bay, Siberia (Thiele, 1909) and another from Monterey, California, that served as the type of *Hanleya spicata* Berry. The dredging of some 40 specimens in the waters of Queen Charlotte Sound, B. C., off Cape James, Hope Island, is therefore, of considerable interest. It was taken in 20-50 fathoms on a gravel bottom.

Ischnochiton cf. *I. golischi* Berry, 1919. A single specimen dredged on mud bottom in 119 fathoms on October 2, 1963, in Georgia Strait 2 miles off Edith Point, Mayne Island, provides the only specimen record north of Monterey Bay. I am grateful to Spencer Thorpe for his identification of this specimen.

LITERATURE CITED

Burch, John Quincy

1942 - 1946. Distributional list of the west American marine Mollusks (from) Proc. Conch. Club of S. Calif., nos. 33 - 63

Oldroyd, Ida Shepard

1927. The marine shells of the west coast of North America. Stanford Univ. Publ. Geol. Sci. 2 (2): 304 pp., 42 plts.

MacGinitie, Nettie

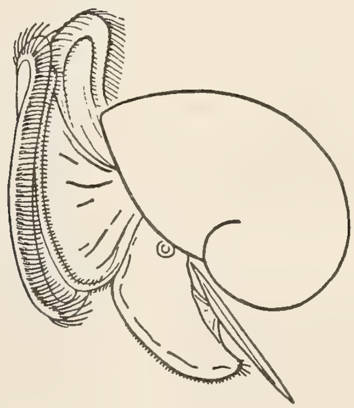
1959. Marine molluscs of Point Barrow, Alaska. Proc. U.S. Nat. Mus. 109: 59 - 208; 27 plts.

Thiele, Johannes

1909. Revision des Systems der Chitonen. Zoologica, Heft 56, Teil I: 1 - 58; 6 plts.

Whiteaves, Joseph Frederick

1880. On some marine invertebrata from the Queen Charlotte Islands (in) G. M. Dawson. Report on the Queen Charlotte Islands. Report of Progress, Geol. Surv. of Canada 1878 - 79, 1880: 190 B to 205 B



New and Otherwise Interesting Species of Mollusks from Guaymas, Sonora, Mexico

BY

DONALD R. SHASKY

AND

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Contribution from the

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(Plates 21 and 22; 1 Text figure; 1 Map)

With miles of rocky coastline, generally free from the heavy wave action and surge of the Pacific Coast, Guaymas is an ideal locality for the skindiving collector. Annually, for the past three years, each of us has averaged three or four diving trips to this port; however our diving and collecting commenced there in 1956.

During the winter months the water temperature at Guaymas dips below 18° C and comparatively few rock dwelling species are found offshore. As the water begins to warm in the spring, dense growths of algae rapidly appear. These algae attach to the rocks in such quantity that the bottom is virtually obliterated from view. Strands of one species extend eight to ten meters above their holdfasts.

In late May and early June the water rapidly warms, killing the algae, so that by the latter part of June large quantities of seaweed have washed ashore, leaving the bottom easy to explore. From mid July to early October the surface temperature hovers around 30° C. During this period many species are spawning, making collection and selection of specimens much easier.

The following list of shells represents species that we have taken at Guaymas both by "free diving" and with the use of SCUBA.[1] This is by no means complete, but represents those species that have not previously been reported from this locality or were recorded from dead material only. Unless otherwise specified, the collecting locality is just northwest of a small cove known locally as Bahía Saladita and designated as "(1) Cove" on the map showing the Guaymas collecting localities. Another collecting area which apparently lacks a name is the small rocky reef just north of the entrance of Bacochibampo Bay, identified by the number (2). The other two localities mentioned are north of San Carlos Bay, "(3) Cove" and Ensenada Lalo.

LIST OF SPECIES

Cymatioa electilis (Berry, 1963). Pl. 21; figs. 7, 8; text fig. 1. Recently described from Manzanillo, Colima, Mexico. Specimens were found buried in muddy sand under rocks 10 m below the surface. (DRS)

In the past few months this species has been the center of considerable discussion. It was originally described by Berry (1963) as *Crenimargo electilis gen. nov. et spec. nov.* Since its publication it has been suggested that the genus would have to stand as a *nomen nudum* as no type species was designated in the original description. As Dr. Myra Keen pointed out (personal communication; 7 May 1964) the International Code of Zoological Nomenclature provides four ways by which a type can be fixed in the original publication [Article 68] to be applied in the order of precedence. First is original designation, second is use of *typicus,* third is monotypy, fourth is tautonymy.

The Code recognizes monotypy as a valid means of fixation and Dr. Berry fulfilled the requirements under monotypy, for there is a single nominal species, and there is also an adequate "indication" for the genus in the form of a differential diagnosis.

The question of validity of *Crenimargo* became unimportant when it was learned that the name was preoccupied necessitating a new name. Dr. Berry has recently

[1] Self-Contained Underwater Breathing Apparatus

(29 July 1964) provided us with the new generic name and fixed the type species as follows:

Genus *Cymatioa* Berry, 1964; *nom. nov.* for *Crenimargo* Berry, 1963, [Leaflets in Malacology, 1 (23) : 140], *nomen praeoc.*

Type species: *C. electilis* Berry, 1963.

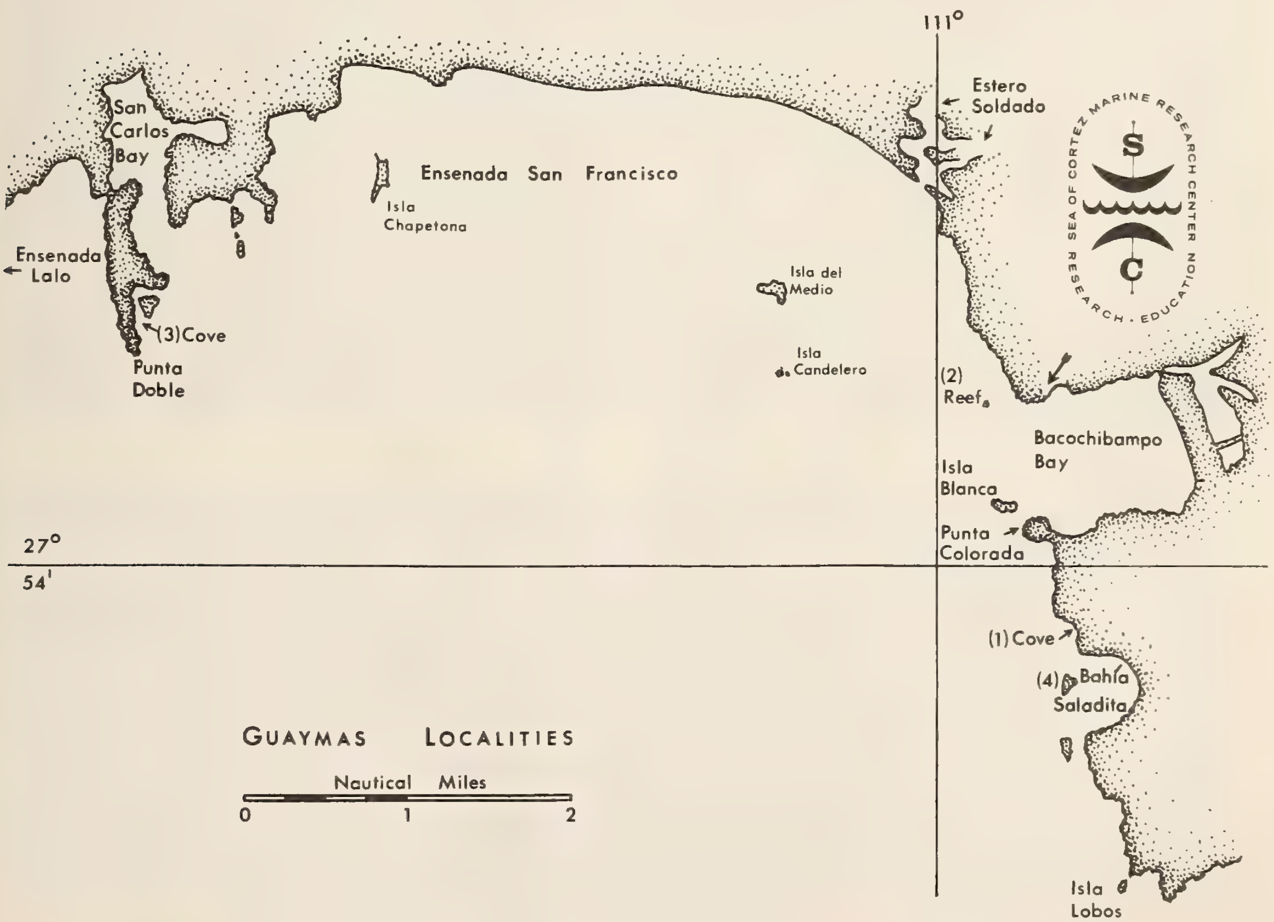
Vanikoro aperta (Carpenter, 1864). Pl. 21; figs. 9-11. Living in colonies under rocks in depths of 2 to 10 m. The largest specimen measures 10.6 x 11.4 mm.

Dr. Myra Keen (personal communication, 7 May 1964) requested us to point out that the illustration she used for *V. aperta* [Keen, 1958; p. 311, fig. 230] had been incorrectly labelled and that at the time she had no way of verifying the identification. Since the figure of the holotype USNM No. 15897 in Palmer [1963, pl. 66, fig. 1] is poor, two additional views of the distinctive early sculpture are shown here.

Text figure 1: *Cymatioa electilis* (Berry, 1963); internal hinge area of left valve showing ligament and cardinal teeth (x 8)

Cheilea corrugata (Broderip, 1834).
This, like the preceding species, lives in colonies. Taken under rocks 8 to 10 m below the surface. (DRS)

Polinices caprae (Philippi, 1852).
One dead specimen from a sandy bottom near rocky rubble at 10 m. (DRS)



Bursa caelata (Broderip, 1833).
Fairly common at Panama and occasionally taken at Mazatlán; one living specimen at a depth of 12 m. (DRS)

Pterynotus pinniger (Broderip, 1833).
One of us (Shasky, 1960) has previously reported taking live specimens of this beautiful species at Guaymas (while trawling over a mud bottom). The specimens reported here were exposed on the sides of rocks at 10 m. We consider *P. pinniger* to be synonymous with *P. inezana* Durham, 1950. (See Emerson, 1960, for a further discussion of this complex). (DRS, GBC)

Ocenebra carmen (Lowe, 1935). Plate 21; fig. 6.
Unreported since the original description, although a few specimens were trawled in the Loreto Channel off Carmen Island, Gulf of California on the Ariel Expedition (GBC). Several specimens taken from under rocks at a depth of 8 to 10 m. (DRS, GBC)

Phyllocoma scalariformis Broderip, 1833.
Two living specimens collected from under partially buried rocks at a depth of 10 m. (DRS, GBC)

Typhis (Typhisopsis) coronatus Broderip, 1833. Pl. 21; figs. 2, 3.
This species is rarely taken by the shore collector or diver, but it is rather common offshore. When a locality is dredged where it is known to occur, as many as ten specimens may be brought up in one haul of the dredge. For discussion of this species and synonymy see Keen & Campbell, 1964. One dead specimen (21.8 x 12.8 mm) was obtained from the 15 m depth. (GBC)

Typhis (Typhisopsis) grandis A. Adams, 1855. Pl. 21; fig. 1.
Two large dead specimens of this species (38.8 x 23.0 mm & 25.4 x 18.2 mm) were found at the edge of the sandy area at approximately 15 m. The systematic position of this species will be clarified in another study currently in progress; therefore, it will not be discussed here except to say that *T. grandis* A. Adams is not a synonym for *T. coronatus* Broderip based on the type material in the British Museum (Natural History). Another specimen was collected in 3 m from the cove between Hotel Playa de Cortez and Punta Colorada. (DRS, GBC)

Pterotyphis (Tripterotyphis) lowei (Pilsbry, 1931). Pl. 21; figs. 4, 5.
One small specimen taken under a rock at a depth of 2 m in cove (3). This is the first living specimen recorded from the Gulf of California. (DRS)

Anachis incerta (Stearns, 1892).
This varicolored species is quite common at Guaymas under rocks in depths of 2 to 12 m. (DRS, GBC)

Bailya anomala (Hinds, 1844).
One living specimen from under a rock resting on a gravel bottom. This extends the range about 1750 miles northwestward. (DRS)

Cantharus bilirata (Reeve, 1846).
Recently reported (Shasky, 1961) in the Gulf of California from two dead specimens, we have found numerous specimens of this interesting species under rocks in 8 to 18 m. (DRS, GBC)

Mitra (Scabricula) lignaria Reeve, 1844. Pl. 22; fig. 12.
Although unreported in recent years, we have found one dead and two living specimens. Under rocks buried in mud at a depth of 10 m. Largest specimen measures 56 mm in height. (DRS, GBC)

Mitra (Strigatella) crenata Broderip, 1836. Pl. 22; fig. 15.
We have found numerous specimens of a small miter, none measuring over 10 mm, that seem to belong to this species. Under rocks at depths of 2 to 15 m. (DRS, GBC)

Conus (Conus) tiaratus Sowerby, 1833. Pl. 22; fig. 17.
Three specimens (two of which were living) of this species have been collected from the surface of large rocks at a depth of 5 m. This, we believe, represents the first account of this species from the Gulf of California. (GBC)

Conus (Chelyconus) orion Broderip, 1833. Pl. 22; figs. 18, 22.
Previously unreported from inside the Gulf of California. Two fresh dead specimens taken from the sandy floor around rocky reefs at 10 to 12 m. In the past some authors have considered *C. orion* a synonym of *C. vittatus* Bruguière, 1792 (Pl. 22, figs. 19, 23). For comparison, both species are illustrated with close-ups of the periostracum; it will be noted that the periostracum of *C. orion* has spiral tufting which is absent in *C. vittatus*. (DRS, GBC)

Conus (Cylindrus) dalli Stearns, 1873.
No living specimens have been reported from inside the Gulf of California, although Oldroyd (1918), Emerson (1962) and Hanna (1963) have mentioned beach mate-

Explanation of Plate 21

Figure 1: *Typhis (Typhisopsis) grandis* A. Adams, 1855 (x 1.33) Figure 2. *Typhis (Typhisopsis) coronatus* Broderip, 1833. (x 2.2) Figure 3. *Typhis (Typhisopsis) coronatus* Broderip (juvenile). (x 3.5) Figure 4. *Pterotyphis (Tripterotyphis) lowei* (Pilsbry, 1931) (x 7.3) Figure 5. *Pterotyphis (Tripterotyphis) lowei* (Pilsbry, 1931) (x 7.3) dorsal view. Figure 6. *Ocenebra carmen* (Lowe, 1935) (x 7.7) Figure 7. *Cymatioa electilis* (Berry, 1963), exterior of left valve (x 2.5) Figure 8. same as no 7: interior of left valve. (x 2.5) Figure 9. *Vanikoro aperta* (Carpenter, 1864) neanic whorls, lateral view. (x 10) Figure 10. same as no. 9 ventral view. (x 3) Figure 11. same as no. 9 apical view. (x 11)

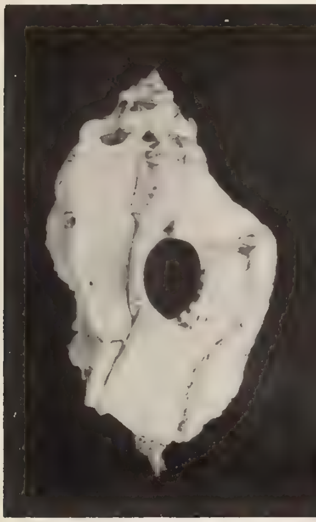


Figure 1

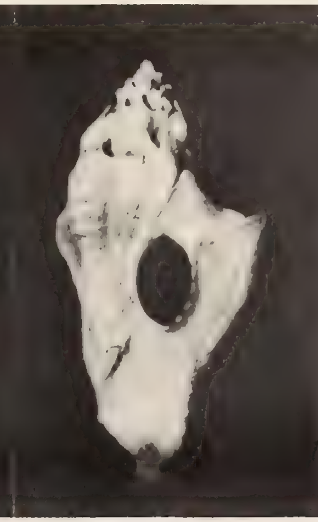


Figure 2


Figure 3


Figure 4


Figure 5

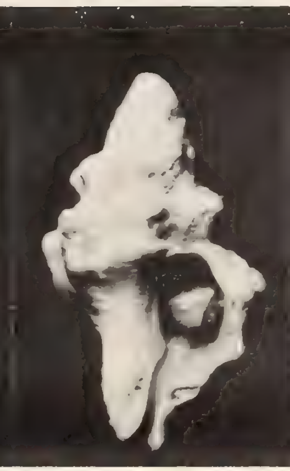
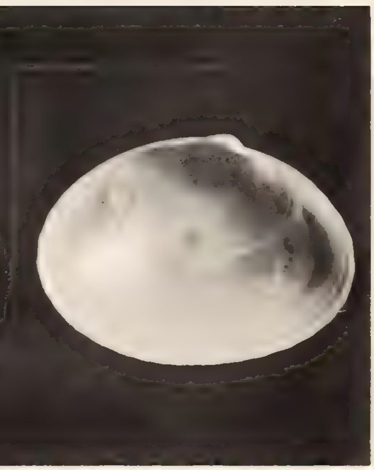


Figure 6


Figure 7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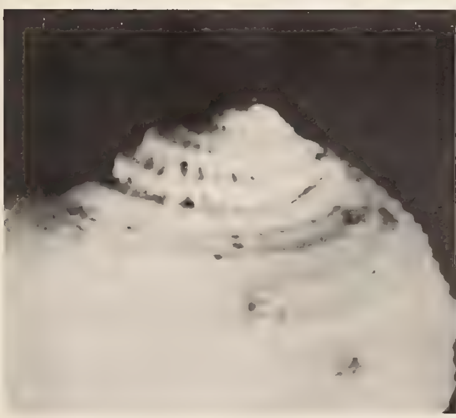
Figure 9

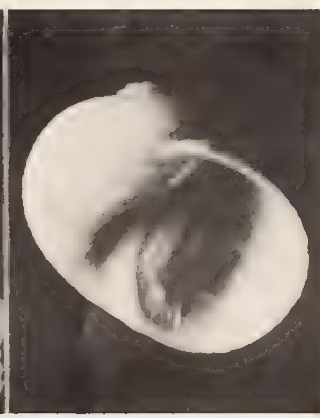
Figure 10

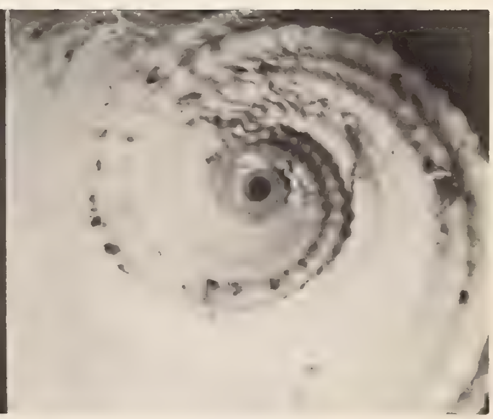
Figure 11

photo. B. Campbell

rial. Two living specimens from Ensenada Lalo in mud under rocks at 15 m. (DRS)

DESCRIPTION OF NEW SPECIES

Trochidae

Calliostomatinae

Calliostoma Swainson, 1840

Calliostoma mcleani Shasky & Campbell, spec. nov.

(Plate 22; figs. 21, 24.)

1961. *Calliostoma angelenum* Lowe, McLean, James H. Trans. San Diego Soc. Nat. Hist., **12** (28): 463. [not *Calliostoma angelenum* Lowe, 1935]

Shell conical, thin; whorls eight; protoconch smooth, white, and polished, approximately one whorl; early whorls dark brown lightening to orange-brown on the body whorl with irregularly spaced oblique stripes of darker brown with an occasional lighter area between; the peripheral three to four beaded lines are checked with white; early whorls sculptured by six beaded spiral threads, the fifth most prominent; on later whorls smaller beaded threads appear bringing the number to twelve on the body whorl; whorls generally flattened giving the shell rather straight sides and diverging at an angle of 70°; base flat with an angular periphery and nine to ten strong beaded cords between which are weak spiral threads; aperture oval; imperforate; columella smooth, straight, and white; outer lip thin, iridescent within; operculum round, thin and transparent horn color, margin entire, nucleus central with several subsequent whorls completing it.

Animal solid bright reddish orange; eye spots black at the base of long tentacles; there are eight long epipodial tentacles which lie posterior to the right and left neck lobes and ventral to the operculigerous disc; the foot is a similar color with numerous small short lines of darker red running parallel to the long axis of the sole of the foot.

Besides the holotype, 87 paratypes and 8 hypotypes were studied. Except for size there was negligible variation in color and sculpture among those specimens collected at Guaymas. Specimens collected in the early spring averaged about one-half the size of those collected during the summer and fall. The hypotypes from the east coast of Baja California were brighter red and smaller in size. The hypotype from Chamela Bay (10.4 x 8.2 mm) has a narrower apical angle and more impressed sutural grooves, but the sculpture is the same as the Guaymas specimens.

Dimensions: Holotype 11.5 mm; maximum diameter 10.0 mm.

Holotype: Stanford University Paleontological Type Collection no. 9742.

Paratypes: Since this species has been taken in rather large numbers, paratypes will be deposited in a number of the larger institutions.

Type Locality: First shallow cove northwest of Bahía Saladita (no. 1 on map) which is approximately midway between Punta Colorada and Punta Lobos, Guaymas, Sonora, Mexico (Lat. 27° 53′ 15″ N.; Long. 110° 59′ W.) in depths of 2 to 15 m.

Range: The northern limit of the range appears to be Bahía de Los Angeles on the eastern coast of Baja California, and the southern limit Chamela Bay, Jalisco, Mexico (see Table 1).

Habitat: This colorful and unique *Calliostoma* has an ecological niche and bathymetric range that protects it from all but the aggressive collector. Populations are most plentiful under medium size rocks (10 to 100 kg) at an

Table 1

Specimen	Collection	Locality	Depth	Collector
Holotype	SUPTC no. 9742	Cove number (1) on map, Guaymas	2-15 m	Donald Shasky
Paratype 1	James McLean coll.	Cove number (1) on map, Guaymas	2-15 m	Donald Shasky
Paratypes 2-44	D. Shasky coll.	Cove number (1) on map, Guaymas	2-15 m	Donald Shasky
Paratypes 45-71	B. Campbell coll.	Cove number (1) on map, Guaymas	2-15 m	Bruce Campbell
Paratypes 72-82	D. Shasky coll.	Island number (4) on map, Guaymas	10 m	Donald Shasky
Paratypes 83-84	B. Campbell coll.	Isla Blanca, Guaymas	14 m	Bruce Campbell
Paratype 85	T. Bratcher coll.	Punta Colorada, Guaymas	ca. 3 m	Twila Bratcher
Paratypes 86-87	D. Shasky coll.	Reef number (2) on map, Guaymas	4 m	Donald Shasky
Hypotype 1	B. Campbell coll.	Cove number (3) on map, Guaymas	3 m	Bruce Campbell
Hypotypes 2-3	B. Campbell coll.	Monserrate Is., Gulf of California	90 m	Ariel Expedition
Hypotype 4	B. Campbell coll.	Loreto Channel, Gulf of California	50 m	Ariel Expedition
Hypotypes 5-7	James McLean coll.	Bahía de Los Angeles, Baja Calif.	"diving"	James McLean
Hypotype 8	Los Angeles County Museum coll.	Chamela Bay, Jalisco, Mexico	30-80 m	George Willett

average depth of 10 m. An occasional specimen, usually dead, is found on a flat rockless area favorable for dredging; likewise a few shells have been taken by "free diving" (without aid of SCUBA or "hookah") in as shallow water as 2 m.

Six specimens have been observed by one of us (GBC) over a period of months in a marine aquarium (capacity 210 liters). The animals are not at all sluggish and move readily about the aquarium usually on the sides, where they can be seen feeding on an alga or diatom growing on the glass, or crawling on the sides of rocks on the sand substrate. Activity is primarily nocturnal.

Remarks: Of the ten or so species of *Calliostoma* occurring in the Panamic province, only two need special comparison; one is *C. angelenum* LOWE, 1935 and the other is *C. leanum* (C. B. ADAMS, 1852). We studied the holotype of *C. angelenum* which is deposited in the San Diego Society of Natural History Type collection, and found it a much different shell, larger in size with the general form of *C. marshalli* LOWE, 1935. Although the holotype of *C. angelenum* is the only specimen known, several characters differentiate it from *C. marshalli* and seem to sufficiently justify retaining *C. angelenum* as a valid species. The type locality for *C. angelenum* is Bahía de Los Angeles, which perhaps explains why James McLean assigned his three specimens of *C. mcleani* to that species. Through the courtesy of Dr. William Clench one of us (GBC) was able to study the lectotype of *C. leanum* (C. B. ADAMS) (MCZ no. 186336); again this is a larger species with impressed sutures, shouldered whorls, and fewer spiral cords with coarser sculpture.

Perhaps a reason why this species has remained undiscovered is its peculiar and rather inaccessible habitat.

We take pleasure in naming this species in honor of our good friend Mr. James McLean who was the first to put this species on record.

MITRIDAE

Mitra RÖDING, 1798

(Strigatella SWAINSON, 1840)

Mitra (Strigatella) sphoni SHASKY & CAMPBELL, spec. nov.

(Plate 22, figs. 13, 14)

Shell moderate size, fusiform, light tan in color under a dark brown periostracum; protoconch rather worn followed by seven subsequent whorls; sculpture of increasingly coarse spiral cords which initially number four and are wider than the interspaces and on body whorl become rather wide V-shaped ridges totalling twelve; axial sculpture wanting except for periodic growth lines; body whorl convex, gradually tapering at base; sutural groove shallow; whorls lacking shoulder; columella with four distinct folds with a fifth, less apparent, anteriorly; outer lip smooth within; aperture sinuous, elongate and narrow; anterior canal broad, open, slightly recurved; siphonal fasciole well developed, concave.

Two paratypes although smaller have the same general form of the holotype. The smallest paratype (Plate 22; fig. 14) retains the more obese form of a subadult shell.

Dimensions: Holotype height 23.3 mm; maximum diameter 8.0 mm.

Holotype: Stanford University Paleontological Type Collection no. 9743.

Paratypes: Two paratypes are in the B. Campbell collection and one in the D. Shasky collection.

Type Locality: First shallow cove northwest of Bahía Saladita (no. 1 on map) which is approximately midway between Punta Colorada and Punta Lobos, Guaymas, Sonora, Mexico (Lat. 27° 53′ 15″ N.; Long. 110° 59′ W.) in depths of 2 to 15 m.

Remarks: Of all the Panamic miters, only one is sufficiently similar to *Mitra sphoni* to warrant special comparison, i.e. *M. crenata* BRODERIP, 1836. This species was described from Ecuador and the length is given by KEEN (1958) as about 17 mm. KEEN also copied the original figure in REEVE (Conch. Icon.) and mentioned that specimens from Guaymas, Mexico in the collection of Dr. S. S. Berry may represent that species. We have a large number of specimens collected at Guaymas of a miter, one of which is figured here, Plate 22; fig. 15, which we

Explanation of Plate 22

Figure 12. *Mitra (Scabricula) lignaria* REEVE, 1844. (x 0.9) Figure 13. *Mitra (Strigatella) sphoni* SHASKY & CAMPBELL, spec. nov., holotype SUPTC no. 9743. (x 2.2) Figure 14. same name as no. 13. paratype. (x 4) Figure 15. *Mitra (? Strigatella) crenata* BRODERIP, 1836. (x 5.7) Figure 16. *Crassispira (Striospira) cortezi* SHASKY & CAMPBELL, spec. nov., holotype SUPTC no. 9744. (x 2.2) Figure 17. *Conus (Conus) tiaratus* SOWERBY, 1833. (x 1.8) Figure 18. *Conus (Chelyconus) orion* BRODERIP, 1833 (x 1.5) Figure 19. *Conus (Chelyconus) vittatus* BRUGUIÈRE, 1792. (x 1.33) Figure 20. *Clathurella (Lioglyphostoma) crebriforma* SHASKY & CAMPBELL, spec. nov., holotype SUPTC no. 9745. (x 6.66) Figure 21. *Calliostoma mcleani* SHASKY & CAMPBELL, spec. nov., holotype SUPTC no. 9742 (x 3) Figure 22. Periostracum of *C. orion.* (x 5) Figure 23. Periostracum of *C. vittatus.* (x 5) Figure 24. same data as no. 21 basal view of holotype. (x 3)

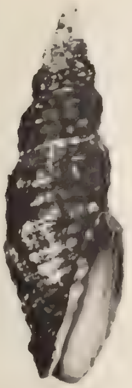
Figure 12


Figure 13


Figure 14


Figure 15


Figure 16


Figure 17


Figure 18


Figure 19


Figure 20


Figure 21

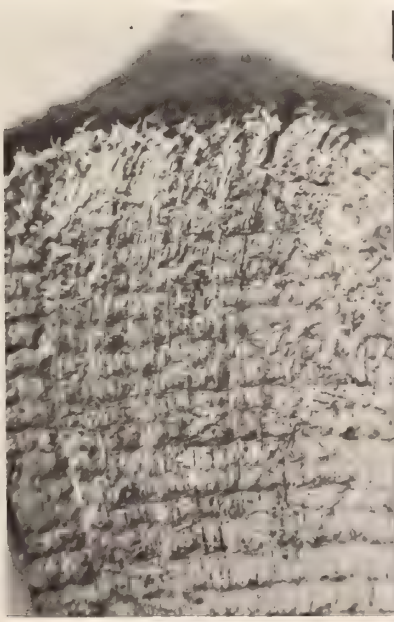
Figure 22

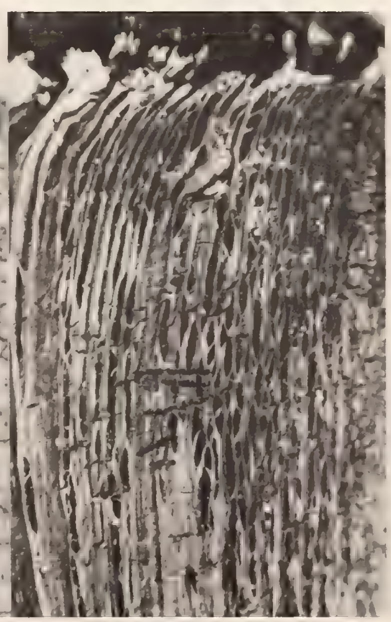
Figure 23

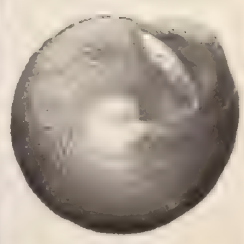
Figure 24

photo. B. Campbell

think represents *M. crenata*. This same form was taken on the Ariel Expedition (1960) off Monserrate Island, Gulf of California (GBC) and in the Loreto Channel, between Baja California and Carmen Island (GBC). Specimens dredged by Mr. James Bailey off Las Palmas, Baja California, 55 miles south of La Paz also seem to belong to *M. crenata*. According to the description, the figure, and specimens we have, *M. crenata* is a black shell with glossy periostracum and smooth sides sculptured by raised threadlike spiral ribs; there is some question whether it is actually a *Strigatella*. In contrast *M. sphoni* is more elongate; shell tan in color, sculptured by wide spiral ribs with much narrower interspaces as seen in *M. belcheri* HINDS, 1843.

The specific name is chosen in recognition of the work done and in progress by Mr. Gale Sphon of Santa Barbara, California, who has added much to our knowledge of the Panamic province, especially in the family MITRIDAE.

TURRIDAE

Clavinae

Crassispira SWAINSON, 1840

(*Striospira* BARTSCH, 1950)

Crassispira (Striospira) cortezi SHASKY & CAMPBELL, spec. nov.

(Plate 22; fig. 16.)

Shell moderate size, biconic, acute, brown under black periostracum with dull purple aperture; protoconch lacking; adult whorls seven; early sculpture of about twenty oblique axial ribs which become reduced in number on later whorls, thirteen on the penultimate whorl and eleven on the body whorl; ribs on later whorls are short, prominent, oblique, slightly curved and narrower than interspaces; spiral sculpture consists of microscopic spiral striae and fine spiral threads; on base of body whorl are about twelve distinct raised spiral cords which fade posteriorly into several indistinct cords; cords lack nodules where they cross axial ribs; suture appressed, obscure, behind a constricted and prominently keeled anal fasciole; aperture narrow, anal notch rounded, moderately deep, reinforced at apical margin by a pad of callus; outer lip thin, arcuate, smooth within, thickened at the edge by a narrow varix, margin notched one millimeter from anterior canal; columella straight with thin wash of callus and lacking any sculpture; siphonal fasciole distinct, concave; canal short, wide, continuous with aperture.

Seven paratypes, having six to eight adult whorls, vary somewhat in shape. Although none are as obese as the holotype, some are more elongate than others. Some specimens have more axial ribs, others less than the holotype. The brown shell under a black periostracum and purple aperture are characters found in all of the specimens.

Dimensions: Holotype height 24.0 mm; maximum diameter 9.8 mm. Largest paratype height 26.8 mm; maximum diameter 9.6 mm.

Holotype: Stanford University Paleontological Type Collection no. 9744.

Paratypes: One in the United States National Museum, three in the D. Shasky collection and three in the B. Campbell collection.

Type Locality: First shallow cove northwest of Bahía Saladita (no. 1 on map) which is approximately midway between Punta Colorada and Punta Lobos, Guaymas, Sonora, Mexico (Lat. 27° 53′ 15″ N. Long. 110° 59′ W.) in depths of 10 to 15 m.

Range: The northern limit of the range appears to be Guaymas. A specimen in the collection of the Los Angeles County Museum seems to belong to this species thus extending the range southeastward to Tenacatita Bay, Jalisco, Mexico. It was dredged in 40 to 80 m by the late George Willett in February, 1938.

Remarks: At first we thought that these shells represented specimens of *Crassispira erigone* DALL, 1919, a species collected in approximately 40 m from Panama Bay. This would have greatly extended its range northwestward. Through the courtesy of Dr. Harald Rehder, one of us (DRS) was able to study the holotype of DALL's species (USNM no. 212368). It was readily apparent that our Guaymas specimens did not represent this Panamic species. *Crassispira erigone* has a spiral sculpture of coarse threads and beading on the base of the body whorl; it lacks a subsutural keel. In *C. cortezi* the beading is lacking on the body whorl, the spiral threads are very fine, and a small subsutural keel is present. From the dimensions given for *C. erigone* it is evident that it is considerably more obese in form.

The specific name for this form is derived from the earlier name for the Gulf of California, Sea of Cortez, which still enjoys usage in Mexico.

Margeliinae

Clathurella CARPENTER, 1856

(*Lioglyphostoma* WOODRING, 1928)

Clathurella (Lioglyphostoma) crebriforma

Shasky & Campbell, spec. nov.

(Plate 22; fig. 20)

Shell minute, slender, acute, light brown with a wide dark brown band at the periphery; within this band is a narrower cream colored band; protoconch of three and one-half translucent pale brown convex whorls with sinuous axial growth lines followed by six subsequent whorls displaying strong cancellate sculpture; suture distinct, somewhat appressed with a narrow fasciole sloping anteriorly which has on later whorls two or more spiral cords; on early whorls sculpture consists of about ten

straight, slender, rounded axial ribs and four spiral cords both equal to interspaces; this number has increased to eighteen axial ribs and five to six spiral cords both narrower than interspaces on the body whorl with eight to nine additional cords on the base; spiral and axial sculpture about equal in strength and at intersections forms nodules; aperture ovate, slightly sinuous; anal notch moderately deep, rounded, close to suture; outer lip convex, narrow, nodulose, edentulous within; anterior canal short but distinct, contracted and slightly twisted.

A single paratype has the same cancellate sculpture as the holotype, but the outer lip is better developed. Originally the paratype was larger than the holotype but loss of the protoconch and neanic whorls has reduced the height to approximately the same as the holotype.

Dimensions: Holotype height 8.1 mm; maximum diameter 3.0 mm. Paratype height 8.5 mm; maximum diameter 3.1 mm.

Holotype: Stanford University Paleontological Type Collection no. 9745.

Paratype: One paratype in the D. Shasky collection.

Type Locality: First shallow cove northwest of Bahía Saladita (no. 1 on map) which is approximately midway between Punta Colorada and Punta Lobos, Guaymas, Sonora, Mexico (Lat. 27° 53′ 15″ N.; Long. 110° 59′ W.) in depths of 7 to 10 m.

Range: Two specimens were dredged by Mr. James Bailey off Cape Pulmo, Baja California which is about 65 miles southeast of La Paz on the Gulf of California. Specimens dredged by us and Gale Sphon in about 50 m off Punta Final (10 miles south of San Luis Gonzaga Bay, Baja California) indicate that the range extends into the northern portion of the Gulf of California.

Remarks: At first glance this species could be mistaken for the columbellid genus *Nassarina*, but the prominent anal notch immediately identifies it as a turrid. It also lacks the heavy axial ribbing usually associated with *Nassarina*.

Clathurella crebriforma should not be confused with any other known species belonging to *Lioglyphostoma;* its small size and fine, beaded cancellate sculpture set it apart from the other west American species.

The recently figured *Pleurotoma gracillima* Carpenter, 1856 (Palmer, 1963) probably represents a small *Crassispira*, and therefore, is not closely related to *C. crebriforma*. The cancellate sculpture appears to be quite similar, however, and on a hasty examination they might be confused with each other. Examination of the anal notch and the anterior canal should quickly dispel any confusion.

ACKNOWLEDGMENTS

In addition to those persons and institutions mentioned in the body of this paper we are grateful to a number of collectors and specialists; especially to Dr. Myra Keen and Dr. Robert Robertson for providing information and photographs of *Typhis* types in the British Museum (Natural History); to James McLean for the loan of material and to Mr. Emery Chace and the San Diego Society of Natural History for making available certain type material.

LITERATURE CITED

Berry, Samuel Stillman

1963. Notices of new eastern Pacific Mollusca — V. Leaflets in Malacology 1 (23): 139 - 146 (30 Sept. 1963)

1964. Notices of new eastern Pacific Mollusca — VI. Leaflets in Malacology 1 (24): 147 - 154 (29 July 1964)

Dall, William Healey

1919. Descriptions of new species of mollusks of the family Turritidae from the west coast of America and adjacent regions. Proc. U.S. Nat. Mus. 56 (2288): 1 - 86; plts. 1 - 24 (8 Aug.)

Emerson, William K.

1960. Remarks on some Eastern Pacific muricid gastropods. Amer. Mus. Novitates 2009: 1 - 15; 7 figs. (18 Aug. 1960)

1962. Results of the Puritan-American Museum of Natural History Expedition to western Mexico. 16. The Recent Mollusks: Gastropoda, Conidae. Amer. Mus. Novitates 2112: 1 - 44; 20 figs. (29 October 1962)

Hanna, G Dallas

1963. West American mollusks of the genus *Conus* — II. Occas. Papers Calif. Acad. Sci., no. 35; 103 pp.; 4 figs.; 11 plts. (28 January 1963)

Keen, A. Myra

1958. Sea shells of tropical west America; marine mollusks from Lower California to Colombia. Stanford Univ. Press, xi + 624 pp.; illus. Stanford, Calif.

Keen, A. Myra, & G. Bruce Campbell

1964. Ten new species of Typhinae (Gastropoda: Muricidae). The Veliger 7 (1): 46 - 57; plts. 8 - 11; 3 text figs. (1 July)

Lowe, Herbert N.

1935. New marine Mollusca from West Mexico, together with a list of shells collected at Punta Penasco, Sonora, Mexico. Trans. San Diego Soc. Nat. Hist. 8 (6): 15 - 34; plts. 1 - 4

McLean, James H.

1961. Marine mollusks from Los Angeles Bay, Gulf of California. Trans. San Diego Soc. Nat. Hist. 12 (28): 449 to 476; figs. 1 - 3

Oldroyd, Ida Shepard

1918. List of shells from Angel and Tiburón Islands, Gulf of California with description of a new species. Nautilus 32 (1): 26 - 27 (July 1918)

Palmer, Katherine Van Winkle

1963. Type specimens of marine mollusca described by P. P. Carpenter from the west coast of Mexico and Panama. Bull. Amer. Paleo. 46: 289 - 408.

Pilsbry, Henry Augustus

1931. *Typhis Lowei*, n .sp. Nautilus 45 (2): 72 (Oct. 1931)

Shasky, Donald R.

1960. Deep water collecting off Guaymas, Mexico. The Veliger 3 (1): 22 - 23 (1 July 1960)

1961. Notes on rare and little known Panamic mollusks. The Veliger 4 (1): 22 - 24; plt. 4 (1 July 1961)

Musculus pygmaeus spec. nov., a Minute Mytilid from the High Intertidal Zone at Monterey Bay, California

(Mollusca: Pelecypoda)

BY

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(Plate 23; 1 Text figure)

INTRODUCTION

In the initial phase of an ecological study of a high intertidal community of organisms at the Hopkins Marine Station in Monterey Bay, California, over the period 1959-1961, numerous rusty-brown specimens of a minute mytilid were frequently encountered. The only individuals available measured between 0.8 and 1.0 mm in shell length and were tentatively identified by A. Myra Keen of Stanford University as juveniles of *Mytilus edulis* Linnaeus, 1758.

On August 26, 1961, many of the same tiny clams were released into a watch glass by a brooding female under observation in the laboratory. Soot-Ryen's (1955) diagnosis of the genera of the Mytilidæ shows that this adult individual is referable to the *Musculus* group. The specimen demonstrates the characteristic features of the genus with respect to shell morphology and musculature which may be summarized briefly as follows: a) anterior margin of shell crenulated, b) anterior adductor muscle distinct, c) radial sculpture absent from the median part of the outer shell surface, d) anterior retractor muscle situated anterior to the umbo, e) umbonal keel low, and f) periostracum without hair-like protuberances. The generic name *Modiolaria* has often been used instead of *Musculus*. As indicated by Dall (1915), however, both of these genera have the same type species, *Mytilus discors* Linnaeus, 1767; *Musculus* is the older name.

Further study of this and other adult specimens in consultation with Dr. Keen revealed the species to be an undescribed form closely related to the more northern species *Musculus taylori* (Dall, 1897). This mytilid was found to be very common in the high intertidal zone, and some information on its ecology and natural history follows the description.

Musculus pygmaeus Glynn, spec. nov.

(Figure 1, a and b, Table 1)

Description: Shell small, stubby, heavily built, and with an inflated appearance; profile of shell with keel-like dorsal margin, oval posterior margin; ventral margin with an irregular contour, indented conspicuously posteriorly and less so anteriorly; ventral portion of anterior margin terminal, forming a prominent forwardly directed protuberance and dorsally with rounded, stout beaks; ventral protuberance of anterior margin clearly visible in a dorso-ventral view as it juts forward between beaks; lateral surface of shell smooth except for concentric growth lines and a ridge that extends obliquely from posterior portion of ventral margin anteriorly towards beaks, terminating near thick mid-body region; two radial striæ extend from lower portion of each beak to anterior edge of ventral margin; some faint nicking is present in a more forward position along edge of protuberance; edge of shell finely scalloped at dorsal keel due to posterior hinge teeth and at antero-ventral margin due to radial striæ; few byssal threads extend through slightly gaping valves of ventral margin; ligament barely visible through widened slit of valves between dorsal keel and beaks; dorso-lateral thick portion of shell chocolate-brown, taking on an olive sheen along ventral margin; iridescent hæmatite red on parts of shell where periostracum is worn away. [1]

DISCUSSION OF PARATYPES

The range in shell length of 102 specimens measured with an ocular micrometer under 10X magnification is 0.6-4.5 mm (Table 1). Larger individuals appear more

[1] All descriptive color determinations in this paper were made with reference to Maerz & Paul (1950).

elongate and inflated than smaller forms; this relation is expressed in terms of the length-width and width-diameter ratios as functions of shell length in Figure 2. The data from which this graph was made are given in Table 2.

Variation of these dimensions with size and other features of the shell are shown pictorially in Figure 2 for a series of four typical individuals ranging in shell length from 1.0-3.9 mm. A keel on the dorsal margin is most evident in larger individuals. In small forms, on the order of 1 mm, the ventral margin has a smooth outline whereas larger specimens demonstrate increasing degrees of indentation of the ventral margin near the anterior and posterior ends. In very large *Musculus pygmaeus* the posterior indentation appears to be notched. A forwardly directed protuberance, forming the antero-ventral border, is not markedly developed in the young, but becomes prominent in forms from about 2 mm in length and greater. Likewise, the beaks appear confluent with the shell among small forms, developing later into distinct knobs. Among all sizes the ventral protuberance is clearly visible below the beaks in a dorso-ventral view. The ridge extending obliquely across the shell anteriorly from the postero-ventral margin is entirely absent in young forms, becoming barely detectable at a size of about 2 mm, and then increasing noticeably in older specimens. Radial striæ while absent in the young are evident in the 2 mm and greater size range. There may be one, two or three radial striæ present. Some forms show a delicate serration in a more forward position on the protuberance. Finally, the position of greatest shell diameter shifts from a dorsal location in small clams to the mid body region in larger individuals.

There is a distinct variation in shell color. Specimens above 3 mm in length agree well with the colors described for the holotype, *viz.* a chocolate-brown color on the dorsal and lateral portions, often grading into an olive sheen along the ventral margin. Also, an iridescent hæmatite red shows on smooth areas of the shell where the periostracum has recently been removed. Smaller individuals, under about 3 mm, generally have a completely hæmatite red shell or this color localized around the central and thicker portion of the body. Numerous shells in the size range 2.0-2.8 mm demonstrated a marginal

Table 1

Location of Type Material of *Musculus pygmaeus,* Field Data and Measurements of Shells.

Material	Museum		Collecting Locality	Collecting Date	Measurements (mm)		
	location	number			length	width	diameter
Holotype	Stanford Univ., Dept. Geology, Stanford, California	9747	Pacific Grove, Calif. 36°37′ N; 121°54′ W	March 4, 1962	3.6	2.1	1.9
20 Paratypes	same as above	9748	same as above	September 20, 1961	2.1±1.1 [1] 0.7—3.4	1.4±0.5 0.5—2.1	1.0±0.6 0.3—1.8
20 Paratypes	Mus. Nat. Hist., Pacific Grove, Calif.	1/81	same as above	March 4, 1962	1.8±1.1 0.6—3.8	1.1±0.7 0.4—2.2	0.9±0.5 0.3—2.0
20 Paratypes	Dept. Zool., Univ. British Columbia, Vancouver	5040	same as above	same as above	1.9±1.1 0.7—4.5	1.2±0.7 0.5—2.5	0.9±0.6 0.3—2.1
20 Paratypes	U.S. National Mus., Washington	635921	same as above	same as above	2.0±1.0 0.7—3.9	1.3±0.4 0.5—2.2	0.9±0.6 0.3—1.9
20 Paratypes	Instit. Marine Biol., Univ. Puerto Rico, Mayagüez	3388	same as above	same as above	1.8±1.1 0.6—4.0	1.1±0.7 0.4—2.2	0.9±0.5 0.3—1.9
1 Hypotype	same as above	3390	Two miles north of Cayucos, California 35°27′ N; 120°56′ W	November 2, 1963	3.1	1.9	1.6

[1] The means and standard deviations and the ranges are given for the measurements of the paratypes.

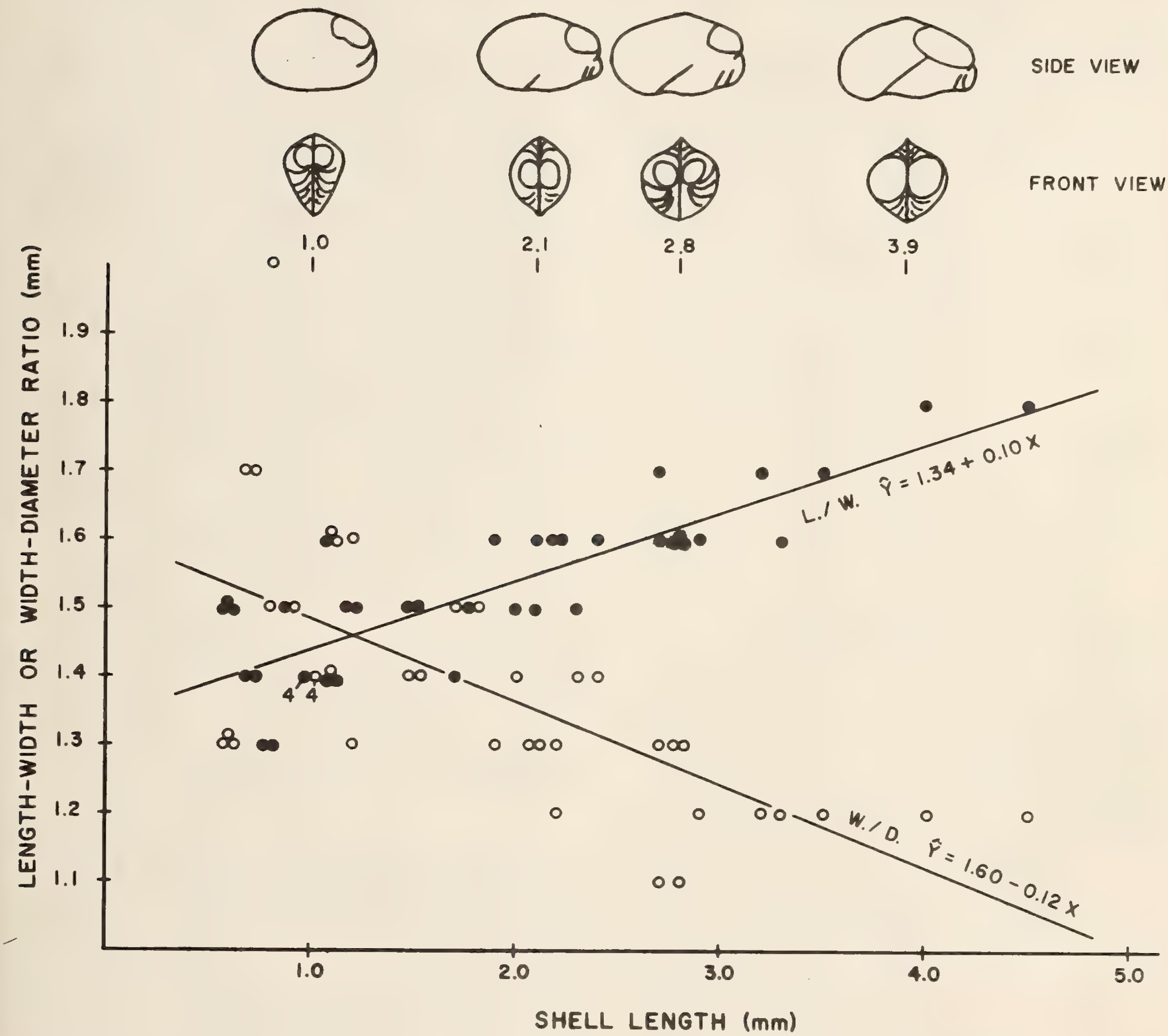

Figure 2: Scatter diagram of length/width (dots) and width/diameter (circles) ratios versus shell length in 40 specimens of *Musculus pygmaeus* from two lots of 20 paratypes each, deposited in the collections of the Institute of Marine Biology, University of Puerto Rico and the Department of Zoology, University of British Columbia. The prediction equations for the two relations illustrated lie along their respective curves. At a shell length of 1.0 mm four individuals each for the length/width and width/diameter ratios are indicated numerically since they occupy the same position on the graph. Side and front view sketches are shown along the top of the graph, illustrating pictorially the shell proportions and obvious shell sculpturing for the four different sized individuals selected. The shell length for each pair of figures is noted just below the front view.

Table 2

Individual Measurements and Ratios of Different Shell Proportions of 40 Paratype Specimens of *Musculus pygmaeus*

Material	Measurements (mm)				
	length	width	diameter	l./w.	w./d.
Institute of	4.0	2.2	1.9	1.8	1.2
Marine Bio-	3.5	2.1	1.7	1.7	1.2
logy, Uni-	3.3	2.0	1.6	1.6	1.2
versity of	2.8	1.7	1.5	1.6	1.1
Puerto Rico,	2.7	1.6	1.4	1.7	1.1
Mayagüez.	2.3	1.5	1.1	1.5	1.4
Museum No.	2.1	1.4	1.1	1.5	1.3
3388	2.1	1.3	1.0	1.6	1.3
	2.0	1.3	0.9	1.5	1.4
	1.9	1.2	0.9	1.6	1.3
	1.5	1.0	0.7	1.5	1.4
	1.2	0.8	0.6	1.5	1.3
	1.2	0.8	0.5	1.5	1.6
	1.0	0.7	0.5	1.4	1.4
	1.0	0.7	0.5	1.4	1.4
	0.9	0.6	0.4	1.5	1.5
	0.7	0.5	0.3	1.4	1.7
	0.6	0.4	0.3	1.5	1.3
	0.6	0.4	0.3	1.5	1.3
	0.6	0.4	0.3	1.5	1.3
Department	4.5	2.5	2.1	1.8	1.2
of Zoology,	3.2	1.9	1.6	1.7	1.2
University	2.9	1.8	1.5	1.6	1.2
of British	2.8	1.8	1.4	1.6	1.3
Columbia,	2.8	1.7	1.3	1.6	1.3
Vancouver.	2.7	1.7	1.3	1.6	1.3
Museum No.	2.4	1.5	1.1	1.6	1.4
5040	2.2	1.4	1.2	1.6	1.2
	2.2	1.4	1.1	1.6	1.3
	1.8	1.2	0.8	1.5	1.5
	1.7	1.2	0.8	1.4	1.5
	1.5	1.0	0.7	1.5	1.4
	1.1	0.8	0.5	1.4	1.6
	1.1	0.8	0.5	1.4	1.6
	1.1	0.7	0.5	1.6	1.4
	1.0	0.7	0.5	1.4	1.4
	1.0	0.7	0.5	1.4	1.4
	0.8	0.6	0.3	1.3	2.0
	0.8	0.6	0.4	1.3	1.5
	0.7	0.5	0.3	1.4	1.7

chrome lemon band extending from the antero-ventral border around to the posterior edge of the ligament. The smallest forms are often entirely of a hæmatite red. The absence of red and predominance of brown coloration in the largest specimens, except where the periostracum has been worn away, seems to be a result of the increase in thickness of the shell with age.

The interior of the shell in adult *Musculus pygmaeus* is iridescent over a blush rose background. The lateral diagonal ridge and the radial striæ are evident but less conspicuous internally. The posterior hinge teeth are strongly developed and are located along the dorsal margin in the region of the keel. Adult specimens usually have five or six hinge teeth in this position. Anterior or cardinal hinge teeth, which number three or four, are located at the forward edge of the protuberance at the anterior margin.

The shell musculature agrees with the descriptions given by PELSENEER (1911) and SOOT-RYEN (1955) for the genus, and can be further characterized for this species as follows. In accordance with the anisomyarian condition of the Mytilidæ, the posterior adductor of *Musculus pygmaeus* is relatively very stout where it is inserted on the shell in a postero-lateral position from the dorsal keel. The anterior adductor muscle is not strongly developed. It is attached to the inner surface of the forwardly directed protuberance, in a position anterior to the umbo. The anterior retractor muscles, located forward of the anterior adductors, are long, running straight from their proximal origin on the foot to insert on the inner surface of the beaks. The posterior pedal retractor muscle fans out at its site of insertion on the shell; it extends posteriorly from the dorsal keel and terminates above the point of insertion of the posterior adductor muscle.

COMPARISON WITH CLOSELY RELATED SPECIES

Of the eleven species and one subspecies of *Musculus* on the western coast of North America (OLDROYD, 1924), *M. pygmaeus* resembles closely *M. phenax* (DALL, 1916) and *M. taylori*. Both *M. phenax* and *M. taylori* are small species in the genus, the holotype of the first measures 7.7 mm in length (DALL, 1915), and the holotype of the second measures 5.5 mm in length (DALL, 1897). The mean shell length and range, respectively, of a series of 15 specimens of *M. phenax* from the type lot deposited in the museum at Stanford University are 3.6±2.6 and 0.9—7.7 mm. Five specimens of *M. taylori*, including the holotype collected from Foul Bay, Victoria, British Columbia and four specimens from the Stanford University museum, gave a mean shell length and range, respectively, of 5.3±0.2 and 5.0—5.6 mm. Thirteen other paratypes of *M. taylori* from Victoria (deposited in the United States National Museum) range in shell length from 4.9 to 6.9

mm. These data show that *M. pygmaeus* is the smallest of the three species (as noted earlier, the largest individual has a shell length of only 4.5 mm, and the series of 20 paratype specimens with the greatest mean shell length measures 2.1 ± 1.1 mm).

The standard deviation in *Musculus phenax* is relatively high—seven individuals measured less than 1.4 mm in length and eight greater than 4.0 mm. Since these specimens are from the type lot they were not dissected, but inspection into the interior of the shell through the gaping valves showed that this species, like *M. pygmaeus*, broods its young. The very small specimens in this sample probably represent young released recently from the adults. Eight specimens of *M. phenax* within the same size range as *M. pygmaeus* demonstrated similar length-width and width-diameter ratios in relation to shell length. *Musculus taylori*, although larger than *M. pygmaeus*, also seems to demonstrate these same shell proportions.

None of the three species shows radial sculpturing of the shell, but radial striæ are present and least evident in *Musculus phenax*. Only *M. phenax* and *M. pygmaeus* possess a prominent keel on the dorsal margin, whereas an oblique ridge is present only in *M. pygmaeus* and *M. taylori*. The ventral margin of *M. pygmaeus* is strongly indented near the anterior and posterior ends, less obviously indented in *M. taylori* and virtually smooth in *M. phenax*.

All three species inhabit shallow water, *Musculus taylori* in tide pools, *M. phenax* among algae and *M. pygmaeus* relatively high on the shore in holdfasts of the red alga *Endocladia muricata* (Postels & Ruprecht) J. G. Agardh, 1847. Presumably *M. phenax* lives in the intertidal zone since it was found in association with *Mytilus edulis*, which according to Shelford, *et al.* (1935) has an intertidal distribution in the vicinity of Victoria, British Columbia.

Musculus phenax and *M. taylori* have a more northerly distribution than *M. pygmaeus*. The type locality of *M. phenax* is St. George Island, Pribiloff group, Bering Sea. *Musculus taylori* has not been reported as far south as Monterey Bay, California (Smith & Gordon, 1948), and apparently is known only in the vicinity of the type locality at Victoria, British Columbia (Burch, 1945); this represents a geographical separation of 12° latitude or about 880 miles. One specimen of *M. pygmaeus* has been collected as far south as Cayucos, California (Table 1, hypotype), about 90 miles from Monterey Bay.

The possibility that *Musculus pygmaeus* is a known form introduced into the Pacific Coast of North America from some other similar environment demands close scrutiny. Many mollusks have been introduced into California from Japan in recent years with shipments of the oyster *Crassostrea gigas* (Thunberg, 1793); Bonnot (1935) in 1930 found 23 species of Japanese mollusks associated with this oyster at Elkhorn Slough, about 15 miles north of Monterey, California. McLean (1960) recently reported on the abundance in Elkhorn Slough of one of the same species reported by Bonnot, *viz. Batillaria cumingi* (Crosse, 1862). *Musculus pygmaeus* was compared critically with the original accounts or other detailed descriptions of the 11 species of *Musculus* which appear in Kuroda & Habe's (1952) check list and bibliography for the marine mollusks of Japan. The results of this comparison demonstrate that *M. pygmaeus* is distinct from all of these forms.

That *Musculus pygmaeus* was not introduced from the East Coast of North America was proved by an examination of the descriptions of the species listed by Johnson (1934). Numerous specimens of *M. lateralis* Say, 1822, a small ovoviviparous nestler, whose description agrees in some particulars with *M. pygmaeus*, were examined and found to be very different.

It is noteworthy that the population of *Musculus pygmaeus* living in the intertidal zone at Monterey Bay, California has the shortest shell length of all described species in this genus. Other small species reported in the literature (only the dimensions of the holotypes were given) are *M. arcuatus* (Gould, 1861) and *M. skomma* (McLean & Schwengel, 1944) each with a shell length of 5 mm.

ECOLOGICAL OBSERVATIONS

Musculus pygmaeus was found to be an important member of a high intertidal community of organisms dominated by the red alga *Endocladia muricata* and the acorn barnacle *Balanus glandula* Darwin, 1854 on the rocky coast in Monterey Bay, California (Glynn, in press). This particular association of organisms forms a band of approximately two feet in width, centered at a mean absolute elevation of 4.6 ft. in height above tidal datum. The lower and upper margins of this belt demonstrated a mean height above tidal datum of 3.7 and 5.8 ft., respectively, with exposure to the atmosphere amounting to 46% of the total time for the lower level and 95% for the upper level.

Musculus pygmaeus lives in intimate association with *Endocladia;* it attaches to the blades of the holdfast of the alga with its byssal threads. This mytilid has an erratic spatial distribution—being completely absent from extensive surfaces dominated by the alga or very abundant in other, seemingly identical localities. It was found in greatest abundance, but sporadically, at the lower margin of the association, especially in exposed, wave-swept areas. It was abundant throughout the year.

The mean occurrence at the low, center, and high levels was 11,260, 7,795, and 10 individuals/m^2 (extrapolated

from 400 cm^2 quadrat samples collected from the rock surface). In the same order, these gave mean dry weight biomass measurements of 10,390, 1,830 and 2.5 mg/m^2, equivalent to 2,078, 360, and 0.5 mg protein/m^2.[2] Compared with 30 other forms characteristic of the center of the *Endocladia-Balanus* association, *Musculus* ranked slightly under 4% numerically of the total mean composition and contributed a protein content of about 0.2% to the association.

To determine the absolute and relative abundance of *Musculus* actually living in the holdfasts of separate thalli of *Endocladia* three plants were removed from the substratum intact, including all animals living within the alga or clinging to the basal branches. The samples were collected at random from a dense stand of *Endocladia,* which had previously yielded numerous specimens of *Musculus,* and preserved in 70% ethyl alcohol. This area is located on the rocks at the Hopkins Marine Station, in a small, exposed surge channel on the small island immediately east of the Agassiz Laboratory. All of the larger animals, down to a minimum size of the smallest *Musculus* or about 0.5 mm, were sorted out from the samples and counted and the dry weight of each tuft of alga recorded.

It is apparent from the tabulation of absolute numbers (Table 3) of the 20 odd forms enumerated that *Musculus pygmaeus* was consistently the most numerous species present. The maximum number recorded was 1,065 individuals in the second tuft (sample 2) and the minimum was 398 individuals in the smallest tuft (sample 3). *Mytilus californianus* Conrad, 1837 was also very common, ranking second in abundance in samples 1 and 2, and fourth in sample 3. *Lasaea cistula* Keen, 1938 was relatively numerous in sample 3, with 46 individuals. Other abundant forms in the thalli were: one undetermined oligochæte species, syllid polychætes, *Balanus glandula, Dynamenella glabra* (Richardson, 1899), *Allorchestes ptilocerus* Derzhavin, 1937, *Agauopsis* sp., and *Filicrisia franciscana* (Robertson, 1910).

In terms of mean absolute abundance per gram dry weight *Musculus* demonstrated a value of 450.0, equivalent to a very high relative abundance of 78.1% (Table 4). *Mytilus* and *Lasaea* ranked second and third, with relative abundances of 9.8% and 2.4%, respectively.

Neither Colman (1940) nor Wieser (1952) in their studies on the animals inhabiting intertidal seaweeds on English shores include the genus *Musculus* as an important faunal element. Colman did not find *Musculus* in the lichen *Lichina pygmaea,* Linnaeus, 1758 which is apparently the ecological equivalent of *Endocladia,* and encountered only a single juvenile specimen of *M. marmoratus* (Forbes, 1838) in the predominantly subtidal brown

[2] This latter set of values is based on a mean nitrogen content of 3.2% and the assumption that proteins contain 16% nitrogen (Fruton & Simmonds, 1958, p. 27).

Table 3

Species & Taxonomic Groups	Samples 1	2	3
Rhodophyta			
Endocladia muricata	2.39 gm	1.76 gm	0.77 gm
Nemertea			
Emplectonema gracile	1	-	1
Annelida			
Oligochaeta			
One undetermined species	12	8	42
Polychaeta			
Nereis grubei	1	-	-
Syllis armillaris	2	-	-
Syllis spenceri	1	-	-
Syllis vittata	5	7	-
Syllidae (immature)	12	10	6
Arthropoda			
Cirripedia			
Balanus glandula	8	5	2
Pollicipes polymerus	-	3	-
Isopoda			
Dynamenella glabra	6	50	-
Amphipoda			
Allorchestes ptilocerus	16	8	-
Acarina			
Agauopsis sp.	29	28	1
Insecta			
Tipulidae (larvae)	-	-	3
Mollusca			
Gastropoda			
Littorina scutulata	-	1	-
Runcina sp.	-	-	1
Pelecypoda			
Lasaea cistula	9	14	46
Musculus pygmaeus	751	1065	398
Mytilus californianus	125	132	23
Saxicava arctica	1	-	1
Ectoprocta			
Filicrisia franciscana	2	2	1
Total number animals/sample	981	1333	525

Number of individuals of the various animal species found living in association with three separate thalli of *Endocladia muricata.* The alcohol-preserved dry weight of each alga is also listed. Omitted is an abundant microfauna, including such groups as foraminiferans, nematodes, harpacticoid copepods, ostracods and rhombognathinid mites. The number of individual colonies of *Filicrisia franciscana* was estimated from a count of the largest intact branches, since numerous small branchlets were probably broken away in handling. Immature syllids and tipulid larvae are groups which contain more than one species each, whereas the Oligochaeta appears to represent a single, undetermined species.

Figure 1 a

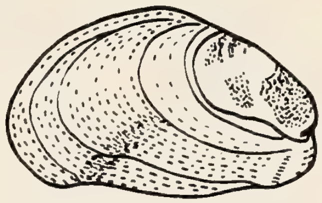

Figure 1 b

Figure 1 c

Figure 1: Photograph showing the right valve of *Musculus pygmaeus* (a); a schematic drawing of the same specimen to the same scale (b); and a photograph showing the right valve of *Musculus taylori* (c).

Table 4

Species	Mean absolute abundance per gram dry weight	Mean relative abundance per gram dry weight
Musculus pygmaeus	450.0	78.1
Mytilus californianus	56.8	9.8
Lasaea cistula	14.0	2.4
Oligochaeta (unident.)	12.5	2.2
Agauopsis sp.	11.8	2.0
Dynamenella glabra	11.4	2.0
Syllidae (immature)	5.7	1.0
Allorchestes ptilocerus	4.9	0.8
Balanus glandula	3.0	0.5
Syllis vittata	2.4	0.4
Filicrisia franciscana	1.0	0.2
Pollicipes polymerus	0.6	0.1
Tipulidae (larvae)	0.6	0.1
Emplectonema gracile	0.4	0.1
Syllis armillaris	0.4	0.1
Saxicava arctica	0.4	0.1
Nereis grubei	0.2	<0.05
Syllis spenceri	0.2	<0.05
Littorina scutulata	0.2	<0.05
Runcina sp.	0.2	<0.05
Total	576.7	

Mean absolute and relative abundance of animal species per gram dry weight in three separate thalli of *Endocladia muricata*. The species are arranged in order of decreasing mean abundance.

alga *Laminaria digitata* (LINNAEUS) LAMOUROUX, 1816. *Musculus* was not found by WIESER in *Gelidium corneum* (HUDSON) LAMOUROUX, 1816, a red alga very similar in shape and structure to *Lichina*, or in any other of the seven species examined.

In view of the virtual absence of *Musculus* it is interesting that the two plant species in the upper intertidal zone on English shores all contain a prolific fauna, with the two pelecypod genera *Lasaea* and *Mytilus* numerically prominent. Although considerable variation was evident in the fauna present in different plants, as in the present study, representative samples of *Lichina* and *Gelidium* contained 155 animals (per gm damp weed) and 1,208 animals (per gm dry weed), respectively. In the same order, pelecypods (*Lasaea rubra* MONTAGU, 1804 + *Mytilus edulis*) made up 61% and 29% of the total number of forms present in these two samples. One gm dry weight of *Endocladia* contained an average of 577 individual animals, with pelecypods amounting to 90% of the associated fauna.

As noted earlier, *Musculus pygmaeus* is ovoviviparous. The developing eggs, situated along the axis of each ctenidium, can be seen through the diaphanous membranes of the gonads. The interlamellar spaces of the most proximal demibranchs serve as brood chambers in adults with relatively few young, *i.e.* of the order of 50 individuals. *Musculus* brooding in the neighborhood of 100 young clams in advanced stages of development have most of the spaces around the visceral organs and the mantle cavity tightly packed with offspring. Two average sized adult specimens of *Musculus* (about 2 mm in length) contained 62 and 132 young each.

Dr. Ruth Turner of Harvard University (personal communication to Dr. Myra Keen) has observed that *Musculus lateralis* is ovoviviparous. *Musculus lateralis* often occurs on boat bottoms as a fouling organism or embedded in the tunic of *Ascidia nigra* (SAVIGNY, 1816). Oviparity has also been observed in this genus. MERRILL & TURNER (1963) have reported on the nest building behavior of *M. discors* (LINNAEUS, 1767) and noted that this species "... deposits its eggs in capsules along the inner lining of the nest where they remain throughout larval and early

postlarval development." *Lasaea cistula,* an abundant erycinid associated with *M. pygmaeus* high in the intertidal zone, likewise broods its young.

It seems likely that *Musculus pygmaeus* breeds throughout the year, since brooding individuals were present in the population at all seasons over a period of three years.

The stomach contents of three specimens consisted of plant fragments and unidentified organic detritus.

ACKNOWLEDGMENT

Dr. Myra Keen first recognized *Musculus pygmaeus* as a possible new species. The author is very grateful to her for providing literature, the loan of specimens, critically reading the manuscript, and for encouragement and interest throughout the study. Discussions with Dr. Rolf Bolin of the Hopkins Marine Station were helpful in the organization of the paper. Appreciation is also expressed for pertinent literature and the one hypotype specimen supplied by Mr. James McLean at Stanford University and for the help of the curators of the various museums into which the material was deposited. A series of paratypes of *M. taylori* was made available by Dr. Joseph Rosewater of the United States National Museum. In conclusion, credit is due Drs. John E. Randall and Carlos G. Aguayo, both of the University of Puerto Rico, Mayagüez, who read the manuscript and offered helpful advice.

LITERATURE CITED

Bonnot, Paul

1935. A recent introduction of exotic species of molluscs into California waters from Japan. The Nautilus **49: 1 - 2**

Burch, John Q. (Editor)

1944 to 1946. Distributional list of the west American marine mollusks from San Diego, California to the Polar Sea. Conch. Club S. Calif., minutes; 2 parts; pagination by issue; plts. 1 - 3.

Colman, John

1940. On the faunas inhabiting intertidal seaweeds. Journ. Mar. Biol. Assoc. U. K., **24: 129 - 183**

Dall, William Healey

1897. Notice of some new or interesting species of shells from British Columbia and the adjacent region. Nat. Hist. Soc. Brit. Columbia, Bull. 2, art. 1: 1 - 18

1915. A new species of *Modiolaria* from Bering Sea. The Nautilus, **28: 138**

Fruton, Joseph S. & Sofia Simmonds

1958. General biochemistry (2nd. ed.) John Wiley & Sons, Inc., New York, pp. 1 - 1077

Glynn, Peter W.

(in press) Community composition, structure and interrelationships in the marine intertidal *Endocladia muricata - Balanus glandula* association in Monterey Bay, California. Beaufortia

Gould, Augustus Addison

1861. Description of new shells collected by the North Pacific Exploring Expedition. Proc. Boston Soc. Nat. Hist., **8: 14 - 40**

Johnson, Charles W.

1934. List of marine mollusca of the Atlantic coast from Labrador to Texas. Proc. Boston Soc. Nat. Hist., **40: 1 - 204**

Kuroda, Tokubei & Tadashige Habe

1952. Check list and bibliography of the Recent marine mollusca of Japan. pp. 1 - 210; 2 maps. Tokyo, Japan. (4 April 1952)

Maerz, Aloys J. & M. Rea Paul

1950. A dictionary of color (2nd. ed.). McGraw-Hill Book Co., Inc., New York, pp. 1 - 208; 56 composite color plates.

Mayr, Ernst, E. Gorton Linsley & Robert L. Usinger

1953. Methods and principles of systematic zoology. McGraw-Hill Book Co., Inc., New York, pp. 1 - 336

McLean, James H.

1960. *Batillaria cumingi,* introduced cerithiid in Elkhorn Slough. The Veliger **2** (3): 61 - 63 (1 Jan. 1960)

McLean, R. A. & Jeanne Schwengel

1944. A new *Modiolaria* from Florida. The Nautilus **58:** 16 - 17

Merrill, Arthur S., & Ruth D. Turner

1963. Nest building in the bivalve mollusk genera, *Musculus* and *Lima.* The Veliger **6** (2): 55 - 59; plts. 9 - 11 (1 Oct. 63)

Oldroyd, Ida Shepard

1924. The marine shells of the west coast of North America. Stanford Univ. Publ. Geol. Sci., **1:** 1 - 247; plts 1 - 57

Pelseneer, Paul

1911. Les lamellibranches de l'expédition du Siboga. Partie anatomique. Siboga-Exped. **53 a:** 1 - 125.

Shelford, V. E., *et al.*

1935. Some marine biotic communities of the Pacific coast of North America. Ecol. Monogr. **5:** 249 - 354

Smith, Allyn G., & MacKenzie Gordon, Jr.

1948. The marine mollusks and brachiopods of Monterey Bay, California, and vicinity. Proc. Calif. Acad. Sci., 4th. Ser., **26** (8): 147 - 245; plts. 3 - 4; textfigs. 1 - 4.

Soot-Ryen, Tron

1955. A report of the family Mytilidae (Pelecypoda). Allan Hancock Pacific Exped., **20:** 1 - 175

Wieser, Wolfgang

1952. Investigations on the microfauna inhabiting seaweeds on rocky coasts. IV. Studies on the vertical distribution of the fauna inhabiting seaweeds below the Plymouth Laboratory. Journ. Mar. Biol. Assoc. U. K. **31:** 145 - 174

New Species of Recent and Fossil West American Aspidobranch Gastropods

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(Plate 24; 1 Text figure)

Five new species have been noticed during my dissertation work on western North American aspidobranch gastropods. They are here described in order to include them in the dissertation. Monographic treatment of the aspidobranch groups is part of a larger project of reviewing the western North American prosobranch gastropods, ranging from central Baja California to Alaska. The groups covered in the dissertation are to be included in the final review which is now in preparation.

A replacement name is presented here for a common species of *Tegula* along the coast of southern California, which has long been misidentified as *Tegula ligulata* (Menke, 1850).

Type material of the new species will be distributed to the U.S. National Museum, the Los Angeles County Museum, and the Stanford University Paleontological Type Collection. Additional paratypes will be sent to the California Academy of Sciences; Museum of Paleontology, University of California at Berkeley; Santa Barbara Museum of Natural History; and the San Diego Museum of Natural History.

I gratefully acknowledge the guidance of Professor Myra Keen, Curator of Malacology in the Department of Geology, and Professor Rolf Bolin in the Department of Biological Sciences of Stanford University, who have directed my dissertation work. This investigation was supported (in part) by a predoctoral fellowship, number 18,613, from the Division of General Medical Sciences, U.S. Public Health Service.

Lirularia bicostata McLean, spec. nov.
(Plate 24, figures 1 and 2)

Description of Holotype: Shell small for genus, whorls four, suture distinct, base and umbilicus rounded; aperture only slightly oblique, circular in cross section; peritreme complete but not detached from base; inner and outer lip simple. Spiral sculpture of a single carina at shoulder on third whorl; on penultimate whorl two prominent raised cords at shoulder and periphery; deep channel at suture. Base bearing two prominent broad cords, two cords of lesser magnitude within slope of umbilicus. Axial sculpture of fine incremental lines, not raised in regular sequence. Color light-brown mottled, white and dark brown areas on main spiral cords. Height 2.4 mm, diameter, 2.3 mm.

Type Material: Holotype, U.S. National Museum, cat. no. 636089. Paratype, Stanford University Paleontological Type Collection, cat. no. 9749. Four additional paratypes (all juvenile), Los Angeles County Museum, cat. no. 1134.

Type Locality: Off north side of Middle Coronado Island, Baja California, Mexico, 45 feet under *Macrocystis* kelp, screened from gravel. J. H. McLean, collector, August 10, 1963.

Additional Localities: South Coronado Island [S. S. Berry Collection, cat. no. 15231, 1 specimen]; Guadalupe Island, Baja California [California Academy of Sciences, locality nos. 24044 (8 specimens), 32819 (3 specimens)].

Discussion: The six specimens comprising the type lot are similarly sculptured and are uniformly light colored. The single specimen in the Berry Collection is gray brown. Specimens from Guadalupe Island (which were recognized in lots of *Lirularia acuticostata* Carpenter, 1864) are variably colored, with yellow, pink, brown and white mottling. These shells show less prominent development of the spiral sculpture and the basal sculpture is obsolete in some of the specimens, but this is also observed in juvenile shells of the typical lot.

Lirularia bicostata, with its reduced number of spiral cords, is similar only to *L. aresta* (Berry, 1941), a species described from the Early Pleistocene Lomita Formation of San Pedro, California, but now known to be living in California at depths of 50 to 100 fathoms off Point Loma, San Diego County, and off Point Pinos, Monterey County. In *L. aresta* the peripheral carina is covered by successive

whorls, but in *L. bicostata* it is exposed. *Lirularia aresta* has a greater number of basal cords than does *L. bicostata.* The aperture of *L. bicostata* is the least oblique of the known species in the genus. This feature is somewhat exaggerated in the figure of the holotype because the lip is slightly broken. *Lirularia bicostata* is the smallest known species in the genus; all specimens observed are less than 2.5 mm high.

Lirularia bicostata should be prevalent in sublittoral zones along the outer coast of Baja California at least as far south as Cedros Island.

The specific name is a Latin adjective meaning "double ribbed," referring to the two prominent spiral cords.

Solariella micraulax McLean, spec. nov.
(Plate 24, figures 3 and 4)

Description of Holotype: Shell of medium size for genus, whorls five, rounded, rapidly inflating; suture distinct, periphery rounded; base slightly convex, sloping evenly into broad umbilicus which penetrates nearly to spire. Aperture circular in cross section, not strongly oblique; inner and outer lip simple, peritreme nearly complete. Spiral sculpture on penultimate whorl of 23 narrow, raised, rounded cords with broader interspaces, approximately 100 cords on final whorl; cords present deep with umbilicus. Axial sculpture of minute raised growth lines passing over spiral cords, most prominent over first four cords below suture. Color brownish above periphery, base and umbilical area cream colored, interior iridescence of pink and green. Operculum multispiral, of 9 whorls, radially striate. Height 7 mm, diameter 8 mm.

Holotype: U.S. National Museum, cat. no. 210530.

Type Locality: Off Alaska Peninsula, vicinity of Shumagin Islands, U.S. Fisheries Commission sta. no. 2848, 55°10′ N. lat., 160°18′ W. long., 110 fathoms, green mud. July 31, 1888.

Additional Locality: "Captain's Bay, Unalaska, Aleutian Island, 16 fathoms, rocky, west of Pinnacles" [U.S. National Museum, cat. no. 219235, height 4.5 mm, diameter 6.2 mm].

Discussion: The two specimens from which this species is known had been unidentified in the collection of the U.S. National Museum. On the basis of the shell I had considered the species to be a *Margarites.* The dried soft parts were present in the shell of the holotype, making it possible to extract and mount the radula (Text figure 1). The radula is typical of *Solariella;* the rachidian tooth is prominently cusped, lateral teeth are cusped only on the outer edge, and the marginal teeth are greatly reduced in number. Radulae of four other species of west American *Solariella* follow the same pattern, some having two rather

Text figure 1: Radula from holotype of *Solariella micraulax* McLean, spec. nov. Only the first three marginal teeth are shown.

than three laterals. The same four species of *Solariella* also have a radially striate operculum similar to that of *S. micraulax.*

From all other species of *Solariella* known from the North Pacific, *S. micraulax* differs in lacking prominent axial sculpture. Only a trace of axial sculpture is suggested by the prominent growth lines passing over the first four spiral cords adjacent to the suture. *Solariella nuda* Dall, 1896, (which has the typical radula) lacks axial sculpture in the mature shell, but the juvenile shell has a definite cancellate sculpture. *Solariella micraulax* most resembles *Margarites (Pupillaria) vorticiferus* (Dall, 1873). In the synonymy of *M. vorticiferus* I include *M. sharpii* (Pilsbry, 1898), *M. ecarinatus* Dall, 1919, and *M. avenosooki* MacGinitie, 1959. *Solariella micralaux* is smaller than *M. vorticiferus,* is not as inflated, has a less oblique aperture, and has spiral sculpture deep within the umbilicus. The latter feature is lacking in *M. vorticiferus* and other species of *Margarites (Pupillaria).*

Solariella micraulax may prove to be not uncommon in Alaska at depths greater than 100 fathoms. Dredging with fine meshed equipment has not been extensive at such depths. Shallower water dredging in Alaska has been more extensive, consequently the record of the hypotype from 16 fathoms may be exceptional.

The hypotype specimen differs markedly from the holotype in possessing a smaller number of spiral cords: six

Explanation of Plate 24

Figures 1 and 2: ***Lirularia bicostata*** McLean, spec. nov. Holotype. (x 13). Figures 3 and 4: ***Solariella micraulax*** McLean, spec. nov. Holotype. (x 4). Figures 5 and 6: ***Tegula (Agathistoma) mendella*** McLean, spec. nov. Holotype. (x 1.5). Figures 7 and 8: ***Homalopoma berryi*** McLean, spec. nov. Holotype. (x 9). Figures 9 and 10: ***Macrarene diegensis*** McLean, spec. nov. Holotype. (x 1.5). Figure 11: Paratype of ***Macrarene diegensis.*** Intermediate growth stage. (x 3). Figures 12 through 14: Paratype of ***Macrarene diegensis.*** Juvenile. (x 5).

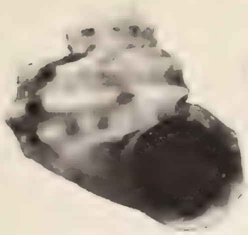
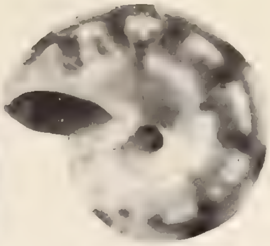


Figure 1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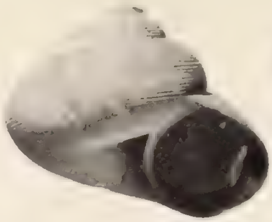
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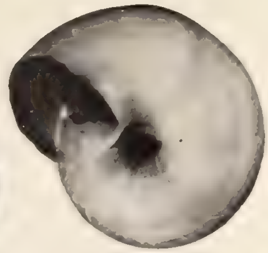
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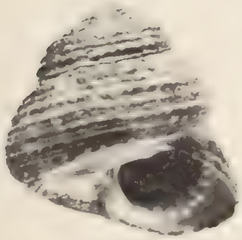
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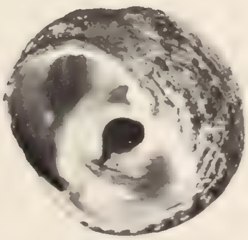
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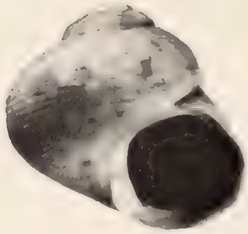
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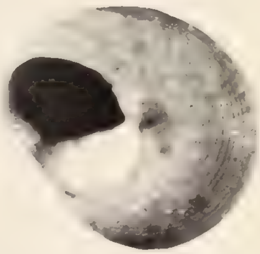


Figure 8

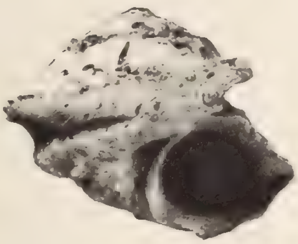


Figure 9

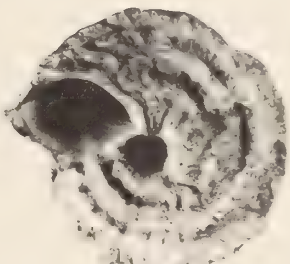


Figure 10

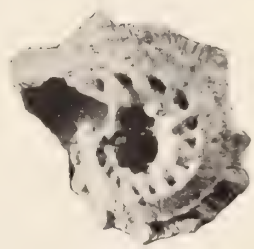


Figure 11

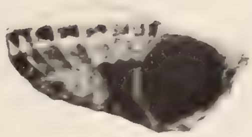


Figure 12

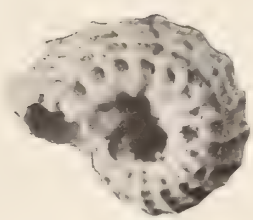


Figure 13


Figure 14

photo. P. Mary

on the penultimate whorl and approximately 40 on the final whorl, including the cords within the umbilicus. The basal cords of the hypotype are numerous and fine, more closely resembling those of the holotype.

The specific name is a noun derived from Greek, meaning "small furrows," with reference to the characteristic spiral sculpture.

Tegula (Agathistoma) mendella McLean, spec. nov.
(Plate 24, figures 5 and 6)

Tegula ligulata (Menke).—*of* authors, not *Trochus ligulatus* Menke, 1850, p. 173.

Omphalius fuscescens (Philippi).—*of* authors, not *Trochus fuscescens* Philippi, 1844, p. 92, pl. 3, fig. 8.

Description of Holotype: Shell large for subgenus, whorls six, suture moderately impressed, periphery rounded; base nearly flat, broadly umbilicate, three denticles at base of columella; aperture oblique, nearly circular in cross section. Spiral sculpture of nodular cords, three prominent cords on third whorl, increasing to eight cords of unequal strength on penultimate whorl, 14 major cords on final whorl and base. Spiral cords nodular in oblique series, corresponding to line of growth; minute spiral threading on and between major cords and basal cords. Ten non-nacreous cords within aperture, terminating in white denticles within lip, less prominent on roof of aperture. Axial sculpture of fine growth lines. Base eroded adjacent to aperture. Operculum multispiral, of about 18 whorls. Color brownish, darker and lighter areas on main cords, columellar area white, whitish nacre within aperture. Height 21.5 mm, diameter, 21 mm.

Type material: Holotype U.S. National Museum, cat. no. 636090. Paratypes, Los Angeles County Museum, cat. no. 1135; Stanford University Paleontological Type Collection, cat. no. 9750. Additional paratypes to be distributed.

Type Locality: Mission Bay, San Diego, California, on rocks of south breakwater inside bay entrance, at low tide and to a depth of 10 feet. J. H. McLean, collector, April 27 and December 11, 1962.

Additional Localities: *Tegula mendella* is a common species in the intertidal zone and the immediate subtidal zone in southern California. Dall (1921, p. 75) recorded *T. "ligulata"* from Monterey to Acapulco, Mexico. The lot from Monterey (U.S. National Museum, cat. no. 14845) is the Californian species but no doubt represents a locality error. Los Angeles County is the northernmost locality known for the species. The southernmost locality record in the National Museum collection is Magdalena Bay, Baja California (cat. no. 24779).

Discussion: It is unfortunate that the name of a well-known species must be changed, but no other course is possible because *Tegula ligulata* (Menke) has been misidentified. The type locality of *T. ligulata* is Mazatlan, Sinaloa, Mexico. The presence of the Californian species has not been verified at Mazatlan, but I have collected there a species of *Tegula (Agathistoma)* more closely answering the original Latin description than does the Californian species. Carpenter (1857, p. 235) redescribed *T. ligulata* in a way that accords with my material from Mazatlan, and I believe that there is no question concerning the identity of *T. ligulata.* Both *T. ligulata* and *T. mendella* are non-carinate on the periphery and non-green umbilicate. *Tegula ligulata* is uniformly smaller, angulate at the base, shows six rather than three raised cords on the third whorl, bears a heavy rugosity below the suture on the fourth and subsequent whorls, and has a non-eroded base.

Carpenter cited the Californian species in 1864 (p. 652): "*Omphalius fuscescens* Phil. Almost identical with *ligulatus,* Maz. Cat. no. 293." Philippi's species was described from Chile. His name cannot apply, because the original description and figure call for a shell with nearly flattened whorls, which is not characteristic of the Californian species. In the Mazatlan Catalogue, Carpenter (1857, p. 235) tentatively listed in the synonymy of *T. ligulata* two species described without locality by A. Adams: *Phorcus californicus* and *P. liratus* A. Adams [original description: Adams, 1853, p. 157]. These two forms apparently remain unrecognized, but cannot refer to the species in question because both descriptions call for shells showing green coloration on the columella, a characteristic of some species of *Tegula (Agathistoma),* but never observed in *T. ligulata* or *T. mendella.* Carpenter (1857a, p. 224) also mentioned a manuscript name of Nuttall, "*Trochus luridus,*" under *Omphalius fuscescens* Philippi. This name could be validated now, but this seems unwise because the name first appeared in Jay's Catalogue (Jay, 1839, p. 71) with the locality "Fayal," an island in the Azores. Thus I have been unable to find an available name for the Californian species.

The name *Tegula mendella* is derived from the Latin noun *menda* (f.), scar, plus the diminutive *-ella,* meaning "little," with reference to the frequently eroded base, a feature not observed in related species.

Macrarene diegensis McLean, spec. nov.
(Plate 24, figures 9 through 14)

Description of Holotype (mature shell): Shell of average size for genus, whorls 4, with strong projecting peripheral keel; suture distinct, umbilicus narrow; aperture oblique,

circular in cross section, peritreme complete. Spiral sculpture of a peripheral carina, producing distinct keel; two faint spiral cords on tabulate surface above keel; broad concave area between keel and first basal carina. Second basal carina subtends base of aperture; a third basal carination borders umbilicus, a fourth faint cord within umbilicus. No axial sculpture on final whorl of mature shell other than raised growth lines. Color chalky white. Height 20 mm, diameter 25 mm.

Description of Juvenile (based on paratype material): Juvenile shell *Cyclostrema*-like; upper surface nearly flat, with two close-spaced spiral cords. Base with four spiral cords rather than three as in adult, crossed by approximately 17 axial ribs, producing definite cancellate sculpture. Axial ribs indistinct on upper surface, but producing stellate projections at extremity of keel. Shells of diameter greater than eight mm exhibit a gradual loss of the second basal keel, while between the third basal keel (second keel of adult) and the umbilical keel, the cancellation becomes more prominent and deep pits are formed (figure 11). All traces of the pitted sculpture are lost in the mature shell.

Type Material: Holotype, Los Angeles County Museum, cat. no. 1136; paratypes, cat. no. 1137. Paratypes, Stanford University Paleontological Type Collection cat. no. 9751. Additional paratypes to be distributed. Only two of the original specimens are mature, the holotype and a paratype 13 mm high. Other specimens are fragmentary or juvenile.

Type Locality: Pliocene, San Diego Formation, Los Angeles County Museum, invertebrate paleontology locality no. 305, 2400 feet E. and 1350 feet S. of the NW. corner of Sec. 8, T. 19 S., R. 2 W., San Bernardino Base and Meridian (USGS topogr. map, San Ysidro quad., ed. 1843). George P. Kanakoff, collector.

Discussion: *Macrarene diegensis* is known only from the Pliocene of San Diego. It is related to *M. coronadensis* Stohler, 1959, and to *M. californica* (Dall, 1908). *Macrarene californica* retains no basal cords in the adult shell, while *M. coronadensis* retains axial sculpture and the first basal cord is as prominent as the peripheral cord. All three of these species evidently pass through similar growth stages. The *Cyclostrema*-like stage of *M. californica* is nearly identical to that of *M. diegensis*. The intermediate pitted stage of *M. californica* is represented by the holotype of *M. pacis* (Dall, 1908), which falls into the synonymy of *M. californica*. The *Cyclostrema*-like stage of *M. coronadensis* is unknown, but I have collected the intermediate pitted stage.

The specific name refers to the type locality, the San Diego Formation.

Homalopoma berryi McLean, spec. nov.
(Plate 24, figures 7 and 8)

Leptothyra bacula (Carpenter).—*of* Arnold, 1907, p. 446, pl. 57, fig. 3.

Homalopoma baculum (Carpenter).—*of* Woodring, 1946, p. 64 [*"bacula"*].

Description of Holotype: Shell small for genus, whorls four, rounded, suture distinct; periphery and base rounded, no umbilical depression. Aperture oblique, circular in cross section. Outer lip simple, columella broad, with low tubercle at base. Heavy callus on base adjacent to aper-

7 2221 7 2221

ture. Spiral sculpture of 15 evenly spaced incised lines on penultimate whorl, about 30 such lines on final whorl and base. Basal sculpture identical to body sculpture. No axial sculpture. Color pink, columellar area white. Height 3.5 mm, diameter, 3.8 mm.

Type Material: Holotype, Los Angeles County Museum, cat. no. 1138; paratypes, cat. no. 1139. Paratypes, Stanford University Paleontological Type Collection, cat. no. 9752. Additional paratypes to be distributed.

Type locality: Lower Pleistocene, Timm's Point Formation, San Pedro, California. Los Angeles County Museum, invertebrate paleontology locality no. 62, on bluff above railroad tracks, below Pacific Boulevard, and east of 22nd Street. G. P. Kanakoff, collector.

Additional Locality: Lower Pleistocene, Santa Barbara Formation, Bath-House Cliff, Santa Barbara, California (Arnold, 1907).

Discussion: *Homalopoma berryi* has previously been confused with the living *H. baculum* (Carpenter, 1864), although the two species are not closely related. Mature specimens of *H. berryi* are smaller than large specimens of *H. baculum,* the shell is thinner than that of *H. baculum,* the suture is more impressed, and the spiral lines are distinct on the body whorl and not obsolete as in *H. baculum.* Living specimens of *H. baculum* generally have brownish shells and occur strictly in the intertidal zone, while *H. berryi* has a pink shell and apparently lived in sublittoral zones, judging from the deeper-water character of other species known from the Timm's Point and Santa Barbara formations.

Woodring (1946, p. 64) undoubtedly was discussing *H. berryi* when he commented: *"H. bacula,* smaller than *H. carpenteri* and sculptured with finer spirals, occurs in all the [Lower Pleistocene] units except the Palos Verdes sand. As in *H. carpenteri,* the rosy color is preserved on many fossils." *Homalopoma baculum* has been reported from Late Pleistocene units and terrace deposits in California, but these records apparently refer to the true *H.*

baculum. There is no evidence that *H. berryi* occurred later than the Early Pleistocene.

The species is dedicated to Dr. S. Stillman Berry of Redlands, California, who has described a number of Early Pleistocene species from California.

LITERATURE CITED

Adams, Arthur

1853. Contributions toward a monograph of the Trochidae, a family of gasteropodous mollusks. Proc. Zool. Soc. London for **1851**: 150 - 192 (pp.150 - 160: 29 June, 1853; pp. 177 to **192**: June 28, 1853)

Arnold, Ralph

1907. New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of Santa Barbara County, California. Smith. Misc. Coll., 50 (pt. 4, no. 1781): 419 to 447; plts. 50 - 58

Carpenter, Philip Pearsall

1855 - 1857.Catalogue of the collection of Mazatlan shells in the British Museum collected by Frederick Reigen. London, xvi + 552 pp.

1857 a. Monograph of the shells collected by T. Nuttall, Esq., on the Californian Coast in the years 1834 - 5. Proc. Zool. Soc. London for 1856: 209 - 229 (Jan. 26, 1857)

1864. Supplementary report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America. Rept. Brit. Assoc. Adv. Sci. for 1863: 517 - 686

Dall, William Healey

1921. Summary of the marine shell-bearing mollusks of the north-west coast of America from San Diego, California, to the Polar Sea, mostly contained in the collection of the U. S. National Museum. Smithson. Inst., U. S. Nat. Mus. Bull. **112**: pp. 1 - 217; plts. 1 - 22.

Jay, John C.

1839. A catalogue of the shells arranged according to the Lamarckian System, together with descriptions of new or rare species contained in the collection of John C. Jay, M.D. 3rd. ed., New York. 125 pp., 10 plts.

Menke, Karl Theodor

1850. Conchylien von Mazatlan, mit kritischen Anmerkungen. Zeitschr. Malakozool. **7**: 161 - 173

Philippi, Rudolf Amandus

1844. Abbildungen und Beschreibungen neuer oder wenig gekannter Conchylien. Kassel, vol. **1**: 77 - 204

Woodring, W. P., M. N. Bramlette, & W. S. W. Kew

1946. Geology and paleontology of Palos Verdes Hills, California. U.S. Geol. Survey Prof. Paper **207**; v + 145 pp.; 37 plts.

{Editor's note: The following correction was received from the author after corrected galley proofs had been returned and after pages had been set up. It was, unfortunately, too late to alter the text on page 131, but we are pleased to be able to include this statement at the end of Mr. McLean's article.}

Tegula eiseni E. K. Jordan, 1936 prior to *Tegula mendella* McLean, 1964.

by James H. McLean

In the present number of The Veliger I described *Tegula (Agathistoma) mendella* McLean, 1964, p. 132, pl. 24, figures 5 and 6), a replacement name for *Tegula ligulata* of authors, not of Menke, 1850. While this paper was in press I discovered that I had overlooked an available name for the species. *Tegula eiseni* E. K. Jordan, 1936 (p. 162, pl. 17, figures 3, 4, and 5) was described as a Pleistocene fossil from Magdalena Bay, Lower California. The holotype (California Academy of Sciences, Type Collection, cat. no. 5487) is a juvenile specimen, 5.8 mm in height and 7.8 mm in diameter. The description and figure clearly represent the California species. *Tegula mendella* must consequently be regarded as an objective synonym of *Tegula (Agathistoma) eiseni* E. K. Jordan.

LITERATURE CITED

Jordan, E. K.

1936. The Pleistocene fauna of Magdalena Bay, Lower California (with an introduction by Leo George Hertlein.) Contr. Dept. Geol. Stanford Univ., 1 (4): 103 - 174; plts. 17 - 19 (13 Nov. 1936)

Mating Behavior in *Littorina planaxis* Philippi

(Gastropoda : Prosobranchiata)

BY

DANIEL G. GIBSON, III

Hopkins Marine Station of Stanford University,
Pacific Grove, California

(7 Text figures)

The habitat of the grey periwinkle, *Littorina planaxis* Philippi (1847), well above high water on rocky western North American shores, exposes this snail to desiccating sun and wind and high temperatures to a greater degree than most other intertidal organisms (Ricketts & Calvin, 1952). This degree of exposure presents several problems to the process of reproduction. Fertilization is internal, which requires that males must have some means of locating females, recognizing them as such, and mating with them. This paper will attempt to explore the mating behavior of *Littorina planaxis* and explain its method of locating other individuals, differences in the behavior of males and females, and the anatomy and mechanics of copulation.

Studies were made at Hopkins Marine Station, Pacific Grove, Calif., during April and May, 1964. Egg-laying and copulating individuals were seen throughout this period. Ricketts & Calvin (1952, p. 13) state that some individuals can be found copulating at any time of year, but spring and summer seem to be the times for heavy occurrences of mating.

LOCATING OF MATING PARTNERS

All movement and any subsequent locating of mating partners in *Littorina planaxis* occurs when the rocks on which these winkles are living are moist. This may be at night or at any time during the day, and may take place even in direct sunlight. Tide height and wave action are two of the main factors that govern rock wetness. Males and females follow mucus trails of other individuals over moist rock, with apparent disregard for the sex of the snail that laid down the trail they are following, using their cephalic tentacles to feel their way along (Peters, 1964). Such following of mucus trails has selective advantage, since it leads winkles to other winkles, which may be potential mating partners.

PAIRING BEHAVIOR

Males differ from females in that they immediately climb upon the shell of any other *Littorina planaxis* individual they encounter, usually over the head end of the shell and often after touching tentacles with the other snail. Once on the shell, the male will migrate to the right side and insert his penis into the mantle cavity of the snail beneath him, assuming the pairing position shown in Figure 1. This position is necessary for copulation, since the genitalia in both sexes are found on the right side, behind the head (for a complete illustration of Littorine anatomy, see Fretter and Graham, 1962, Chapter 2, pp. 14-48). When the animal below is a female, copulation may ensue. However, it appears that success or failure of the tip of the penis in contacting the bursa copulatrix of the female mantle cavity is the only way in which a male

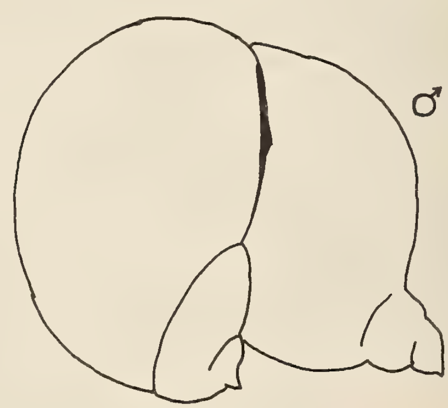


Figure 1: Pairing position, female from above, male from left side. Male's foot entirely attached to female shell, female clinging to substrate. (x 4)

can tell whether he has encountered a female or another male. A male exhibits no defensive reaction to having his mantle cavity explored by the penis of another male, but the male above will soon climb off and seek another mate if his probings do not meet with success. Observations were made of 32 males placed on a moist rock in the laboratory and watched for an hour and a half. No fe-

males were present. During this time, 12 pairs formed, and the length of time that each remained in the pairing position was recorded. None of the male-male pairs observed persisted for more than 8 minutes, and more than half of them broke up in two minutes or less. Because of their short duration, male-male pairs are not prevalent in the field at any one time. Parallel observations of 32 females in the absence of males under the above conditions yielded no pairing or climbing on one another's shells.

This apparent trial-and-error method of finding a mate could be of great selective advantage in the range where *Littorina planaxis* lives.

A male becomes aggressive if he comes into contact with another male on the shell he is exploring or intending to explore. Ten battles resulting from such circumstances have been observed, lasting between 30 seconds and 3 minutes, consisting of the males jerkily pushing each other with the head ends of their shells until one is dislodged. Figure 2 shows such a battle in progress.

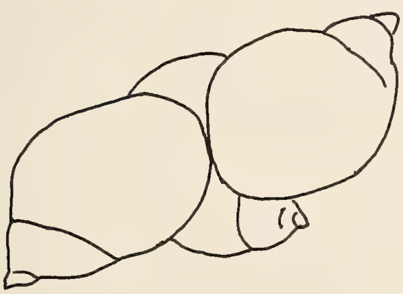


Figure 2: Mating battle, from above. The two males on the third snail will push each other until one is dislodged. This takes from thirty seconds to three minutes. (x 2)

In two cases, the snail, on which the fighting males were, was also a male, but they apparently did not know it, for the victor in each case attempted copulation with the snail beneath him.

Often a third snail will be found very close to or touching two paired individuals. In 50 checks of the sex of this third individual, 48 were found to be males, 2 females. The proximity of the second male to the pair might be due to his just having been pushed off the female, having not yet left the area, or it might suggest a chemo-attraction of males to the vicinity of females.

Laboratory and field studies showed, quite similarly, that normal (heterosexual) pairs persist for quite some time after formation, often spanning an entire moist-rock activity period of 10 hours or more. A field study of pair formation and persistence over one activity period is shown in figure 3. Pairs are seen to form over a wide range of dark and daylight hours, and are seen to persist for greatly varying lengths of time. A certain percentage of snails are to be found paired, with different partners, more than once during the same activity period as Figure 3 also shows.

The amount of pairing occurring at any time in the field seems to be affected by the level of the tide. Figure 4 shows two pairing frequency studies made over 25-hour tide cycles a week apart, demonstrating that the time shift in the tide level causes a concomitant shift in the time of day that the greatest and least numbers of individuals are paired. The area observed was about 1 meter square, containing about 100 *Littorina planaxis* individuals. Each hour the number of pairs and single winkles in the area was counted, the percentage pairing calculated, and plotted. The second week, as the tide came in later in the day, pairing percentage also peaked later. In both studies, pairing percentage rose as the tide came in, and then began to fall as the tide rose further. An increasing amount of splash, capable of dislodging paired snails, since in a pair only the female's foot is attached to the substrate, may account for this.

COPULATION

The trial-and-error behavior displayed by male *Littorina planaxis* in finding females suggests that copulation is the first purpose of pairing, and probably occurs immediately upon finding the female's genital opening. Figures 5a, b, & c illustrate insertion of the penis. It is first extended downward and backward, becoming engorged with blood and elongated (5a); as it continues to elongate, the front edge is pushed into the mantle cavity (5b); the tip trails in after the front edge and is eventually inserted in the bursa copulatrix (5c). Involuntary cilia in the penis cause a very rapid flow of sperm and prostatic secretions down the seminal groove that can be observed with a dissecting microscope. The rate of flow here makes it very unlikely that copulation takes very long, and it has been observed that sperm transfer is not always occurring during the entire time the penis is inserted. Of ten cases of copulation observed without disruption, the longest time the penis remained inserted was 15 minutes, more frequently only 4 or 5. The technique of observation was the collection of dry, closed pairs stuck together with mucus, which were then placed under seawater with the

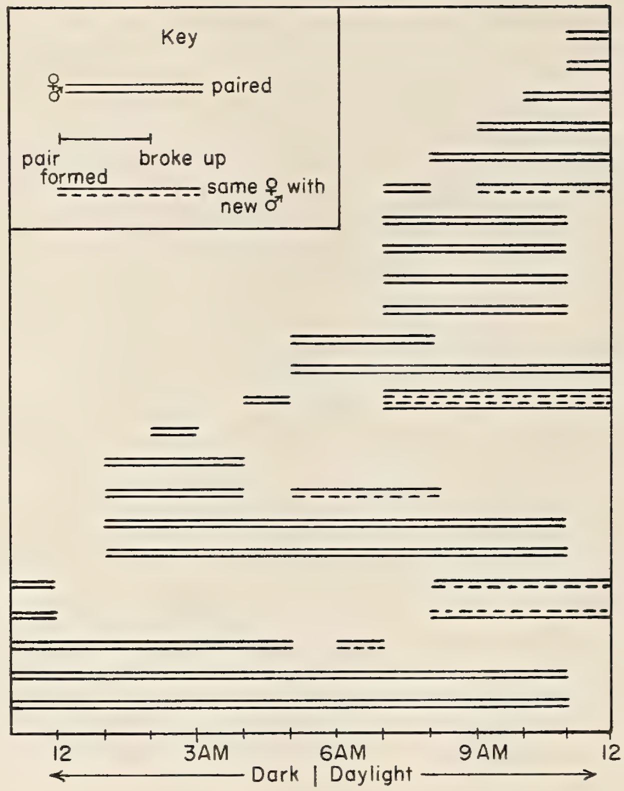


Figure 3: Record of field study of pair formation and persistence over one moist-rock activity period, showing that pairs form over a wide range of dark and daylight hours, and persist for greatly varying lengths of time. One individual may pair more than once during a single activity period.

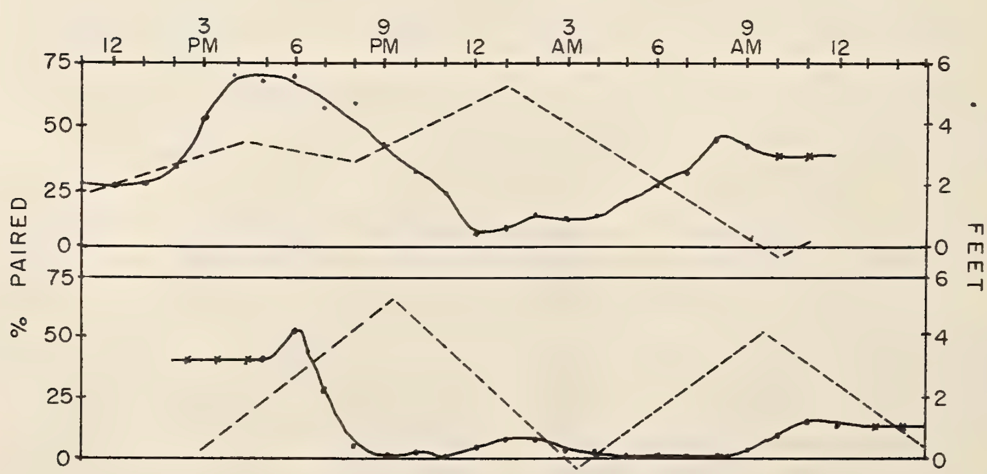


Figure 4: Two field studies of pairing percentage made over two 25-hour tide cycles one week apart, showing shifting of time of maximum and minimum pairing with tide-level time shift. See text for further explanation. ---- Tide level; ——— % paired. —×—×—× = % paired while snails are dry, drawn into shells, attached by mucus.

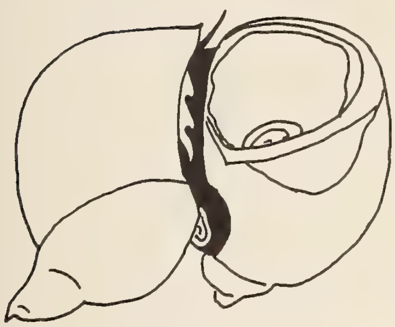


Figure 5 a

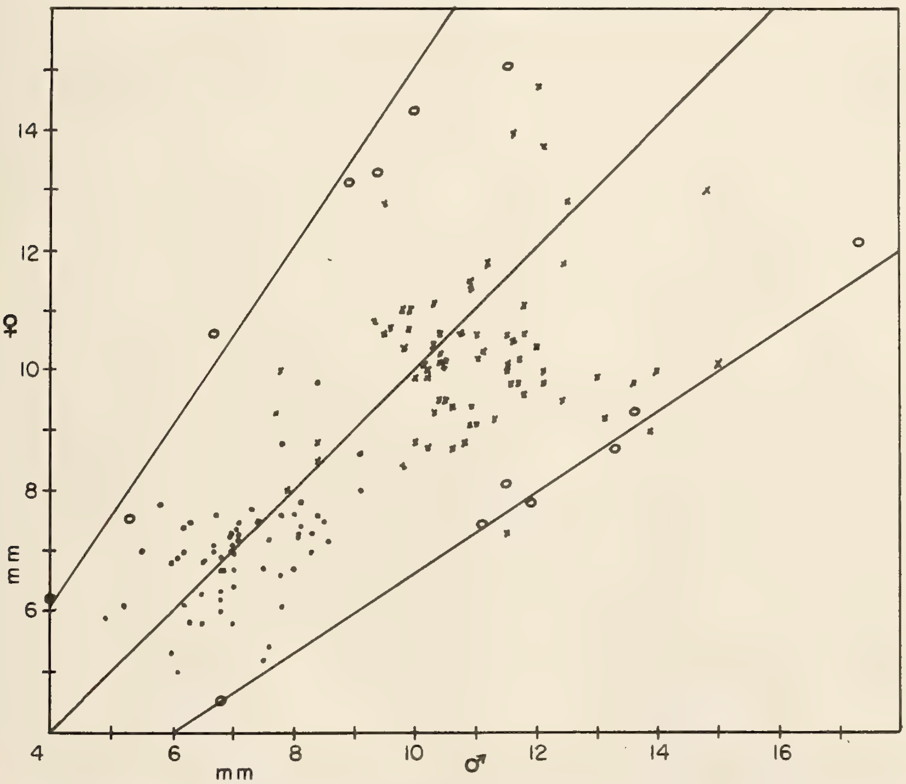
Figure 5 b

Figure 5 c

Figure 5 a: Pair, seen from below, with male extending penis down and back prior to insertion. Female with foot partially attached to glass plate, illustrating obstruction of view by subsequent spreading and flattening of foot. (x 2.5)

Figure 5 b: Male begins insertion of leading edge of fully extended penis into mantle cavity of female; the tip will trail in after. Fretter & Graham (1962) state that the mammaliform glands on the leading edge of the penis may produce secretions which aid in holding the penis in place during copulation.

Figure 5 c: Penis inserted as in sperm transfer. Female is waving foot about in an attempt to contact substrate in order to right herself.



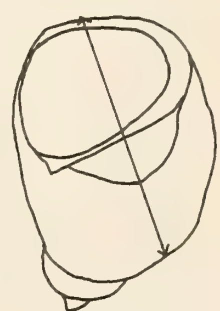


Figure 6 a

Figure 6

Figure 6: Scattergram of size of females plotted against size of males with whom they were paired. Two different populations and several pairs selected for their disproportion are represented. Each symbol between the diverging slope lines represents a pair in which the smaller member is at least ⅔ the size of the larger • = population no. 1; 61 pairs. x = population no. 2; 72 pairs. o = the most disproportionate pairs found out of 84 pairs selected for this quality.

Figure 6 a: Method of measurement for Figures 6 and 7, across operculum and columella, from center of aperture lip to widest part of whorl opposite.

female on her back. Under these conditions the snails soon extended themselves, and the male usually attempted to insert the penis. The only drawback to this method of observation is occasional disruption of copulation as the female swings her foot around, trying to find a substrate in order to right herself. An attempt was made to avoid this problem by allowing the female to contact a glass plate with her foot while upside down; however, contact with the plate was followed by a spreading and flattening of the foot, which obscured the view of the penis and the female's mantle cavity.

When the female is righted, the position of the male shell during pairing completely obstructs the view of the penis. Since it is impossible to tell by male shell orientation whether or not the pair is copulating, field studies of duration or frequency of copulation are practically impossible. Disruption of 100 active (extended) pairs in the field revealed only 17 in which the male's penis was extended, so paired snails cannot always be regarded as copulating.

SIZE RATIOS IN MALE-FEMALE PAIRS

A question arises as to what size males will be found paired with what size females in the field, and whether any selection for size of mate occurs. Figure 6 is a scattergram of all the pairs of two different *Littorina planaxis* populations taken from two different areas, in which the size of each female is plotted against the size of the male she was paired with. The method of measurement used for both Figures 6 and 7 is shown in Figure 6a. All symbols between the diverging slope lines in Figure 6 represent pairs in which the smaller member is at least ⅔ the size of the larger. This suggests itself to be the practical limit in size disproportion in pairs found in the field. An overall survey of populations in which only the most disproportionate pairs were selected yielded only 4 out of 84 pairs taken that failed to fall within the suggested limits. A few of these limit-defining pairs are also recorded on the scattergram.

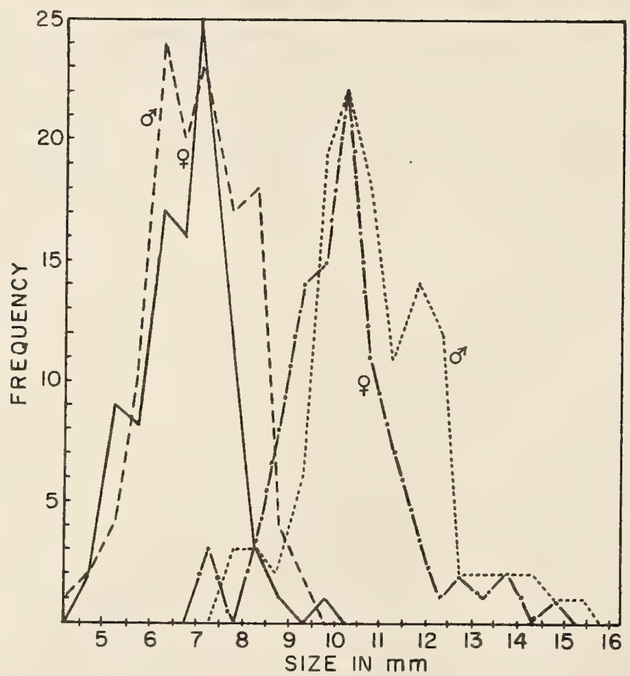


Figure 7: Size frequency by sex in populations 1 and 2 (see Figure 6). All individuals in each ½ mm category are plotted as one point, as there are 14 males between 11.5 mm and 12.0 mm.

——— = population 1; (93) females ---- = population 1; (126) males

—·—·— = population 2; (96) females; ········ = population 2; (120) males

A breakdown of size frequency by sex of the two scattergram populations is presented in Figure 7. Here is suggested one reason why more disproportionate pairs are not found: very large males and females are not found in the same populations with very small individuals. Therefore, in addition to the mechanical problems of copulation between *Littorina planaxis* individuals with grossly disproportionate genitalia, there are undoubtedly many ecological pressures involved which keep large and small snails apart in nature, such as size as a factor in withstanding wave shock, desiccation, etc. However, laboratory experiments in which large males were kept isolated with small females, and conversely, for two weeks yielded only one pair, barely exceeding the ⅔ limit, while evenly sized snails under the same environmental conditions paired readily and often.

SEX RATIO

As Figure 7 indicates, there are generally more males than females in the population. A survey of 100 unpaired individuals yielded a ratio of two males to each female: however, when the population as a whole and the large number of snails that are pairing at any one time are considered, the balance between the sexes is seen to be such that there is probably little or no significance in the greater number of males present.

LITERATURE CITED

Fretter, Vera, & Alastair Graham

1962. British prosobranch molluscs, their functional anatomy and ecology. London, Ray Soc. xvi + 755 pp.; 316 figs.

Peters, Ronald

1964. Function of the cephalic tentacles in *Littorina planaxis* (Gastropoda: Prosobranchiata). The Veliger **7** (2): 143 - 148 (1 October 1964)

Ricketts, Edward F., & Jack Calvin

1952. Between Pacific tides. Stanford Univ. Press, x - xiii; 3 - 502; 46 plts. Stanford, Calif.

Macroscopic Algal Foods of *Littorina planaxis* Philippi and *Littorina scutulata* Gould

(Gastropoda : Prosobranchiata)

BY

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The upper littoral periwinkles of the central California coast are often found in association with a number of the higher intertidal macroscopic algae. The studies and observations upon which this paper is based were made on the Monterey Peninsula, on the central California coast, especially at Mussel Point in the vicinity of the Hopkins Marine Station, and at Pescadero Point. The coastline in these areas consists principally of granite boulders and outcroppings interspersed with sandy beaches, heavily overgrown with larger algae through most of the littoral zone. Observations were made during May, 1964, and therefore do not reflect any seasonal fluctuations that might take place.

Despite the fact that both *Littorina planaxis* Philippi, 1847 and *L. scutulata* Gould, 1849 are a conspicuous part of the upper littoral fauna over much of the Pacific coast of North America, almost nothing has been published about them up to now, and while the eastern United States and European periwinkles are generally better known, information on food and feeding patterns is very scarce. North (1954) analyzed size distribution, erosive activities, and gross metabolic efficiency of both *L. planaxis* and *L. scutulata*. Castenholz (1961) used *L. scutulata* as well as *Acmaea* spp. in his studies of grazing effects on diatom populations. From his observations, he assumed "that the primary food of these gastropods is diatom material" (p. 793), with blue-green algae the principal food in the "supra-littoral" fringe. Ricketts & Calvin (1952) state that *L. planaxis* feeds on detritus and microscopic plants scraped from almost bare rock, and that "certain of the rockweeds *(Pelvetia* or *Fucus)* serve the young periwinkles as a sort of nursery, for it is on their fronds and stems that the young will nearly always be found" (p. 20), an observation for which no evidence has

been seen during this study. Concerning other species, Newell (1958) noted that *L. littorea* ate surface deposits of diatoms and small algae, and also browsed on *Ulva* and *Enteromorpha*.

The answers to three questions were sought in this study. Can these snails eat macroscopic algae? Which algae, if any, are normally part of their diet? How important are these algae in their diets? A number of approaches were used in the attempt to answer these questions. Numerous field observations were made to determine to what algae the snails had access and if they were ever in contact. Principal proof of feeding was based on examinations of the stomach contents of dissected snails, from which ingested tissue fragments could be compared with scrapings from the algae on which the snail was found, or on which it was believed to have fed. In a few cases, feces were also examined for recognizable algal fragments. Several types of laboratory experiments were attempted to supplement field observations. Sometimes it was sufficient to place a winkle together with a dampened piece of alga in a dish. Better results were obtained in an aquarium the contents of which were kept wet, but not submerged, by a fine sea water spray. An aquarium was also rigged to duplicate tidal fluctuations, but conditions were not similar enough to those in the field to get normal responses for any length of time. North (1954) noted that food passed completely through the digestive tract in from 2½ to 6 hours. Thus the stomach contents of any snail kept for six hours with a single type of alga, or starved for six hours and then placed with an alga, could come only from that alga. This seemed to hold true in all cases observed, and provided a simple and reliable check for other types of observations.

A number of difficulties were encountered in the attempt to induce feeding in the laboratory. *Littorina planaxis* has a strong tendency to crawl to the highest part of the dish or aquarium, especially if placed in water. Individuals of both species would frequently cease activity if left undisturbed for more than 6 to 12 hours. Natural conditions, especially with respect to tidal and diurnal fluctuations, proved almost impossible to duplicate, yet it would have been even more difficult to keep track of individual snails in the field or to eliminate unwanted food sources there, especially the ubiquitous "GATGOR" (Green Algae That Grow On Rocks, a term applied to the microscopic flora; work on this aspect of littorine feeding has been done by Foster (see below, this issue). Experimental animals had to be run singly in experiments where starvation was a factor because of the tendency of periwinkles to feed on each others' shells. Additional complications resulted from epiphytic algae growing on the test specimens, and from the rapid decay of certain types of algae, especially *Iridophycus*[1] *flaccidum* and *Laminaria Andersonii*, under conditions available in the laboratory.

A number of criteria were set up by which feeding on any particular alga could be substantiated with a satisfactory degree of certainty. At least two of these three standards had to be met before a snail could be considered to have "fed" on the alga in question: (a) the snail was observed on the alga, preferably actively moving and with the radula active; (b) whole pieces or fragments of tissue were found in the stomach or feces exactly matching in cell size, shape, structure, color, type of chloroplasts etc., scrapings or known forms of the alga in question (usually determined by direct comparison); (c) the animal was starved (kept with no signs of feeding or no food) for at least six hours prior to feeding or dissection, and had stomach contents not dissimilar to fragments of the test alga.

Most of the observations of feeding on any one particular alga are based on only a small number of individuals because of the time involved in making a positive determination of feeding, and, in some cases, because such feeding itself may occur only rarely. Some algae are found over only a small part of the range of *Littorina planaxis* or *L. scutulata*, or snails may feed on them only under particularly favorable conditions. It was assumed, however, that positive proof of feeding on an alga, even if based on only one individual, would indicate a species capability of eating or ingesting the alga, if not a preference for it, and that once such a capability was demonstrated, snails observed on such an alga were probably feeding on it.

Littorina planaxis is generally found in the upper regions of the intertidal zone, on "bare" rocks normally moistened only by splash. The height of this region varies considerably with the amount of exposure to surf. *Littorina scutulata* occurs somewhat lower, and in more protected areas, ranging from about +2 feet up to about +6 feet in some areas. It is frequently found in moderate to heavy growths of algae, and very small individuals occur in large numbers in some horizontal *Balanus* beds. The ranges of the two species of *Littorina* overlap considerably in some areas.

Both species are known to depend on microscopic algae (diatoms, greens, and some blue-greens) as a principal food source (Castenholz, 1961; Foster, this issue), especially where macroscopic algae are scarce or absent, as they are over much of the range of *Littorina planaxis*. However, there are areas in which a considerable macro-

[1] Currently placed in *Iridaea*.

scopic algal flora is available, and it is with these areas that this study is primarily concerned. A number of common algae occur in the vicinity of littorine populations, especially *Cladophora trichotoma* (C. A. AGARDH) KÜTZING,[2] *Endocladia muricata* (POSTELS & RUPRECHT) J. G. AGARDH, *Fucus furcatus* C. A. AGARDH, *Gigartina Agardhii* SETCHELL & GARDNER, *Gigartina cristata* (SETCHELL) SETCHELL & GARDNER, *Iridophycus flaccidum* SETCHELL & GARDNER, *Pelvetia fastigiata* (J. G. AGARDH) DETONI, *Porphyra perforata* J. G. AGARDH, *Rhodoglossum affine* (HARVEY) KYLIN, *and Ulva spp.* *Cladophora* is generally found in cracks, crevices, and tidepools, on horizontal surfaces, sometimes together with *Ulva; Endocladia, Rhodoglossum,* and the gigartinas are frequently associated together in crevices and on rock surfaces, as well as in scattered individual clusters; *Pelvetia, Fucus,* and *Iridophycus* are commonest on sloping surfaces at slightly lower levels; *Porphyra* often covers the tops of boulders and outcroppings.

One area, in which many of the field observations reported in this study were made, includes all of the above species except *Fucus* and in addition has large populations of both *Littorina planaxis* and *L. scutulata*. It is on a granite shelf west of Pescadero Point, at a height of about +4 feet, and was divided for survey purposes into two sections, each of approximately 2 square meters in area. The first is largely horizontal, with a number of crevices up to 10 cm deep and a small tidepool. *Cladophora* is the dominant alga, with some *Endocladia* and *Rhodoglossum* also present; the algae are largely confined to the crevices and the tidepool, the elevated rock areas being bare. The second consists of the vertical west face of the shelf and some of the contiguous horizontal top, about 2 meters from the first area and at the same level. It is almost entirely covered with algae, with *Endocladia, Rhodoglossum, Pelvetia,* and *Gigartina cristata* the most common species, the others present in lesser quantities. One survey showed that the two areas contained 147 *Littorina planaxis* and 329 *L. scutulata*. Surveys were generally made in the morning while the snails were still active from their previous night's wetting, yet had had enough time to feed adequately on the algae.

The feeding behavior of *Littorina planaxis and L. scutulata* seems to be a combination of random activity and preferential movement. In the laboratory, snails are frequently observed scraping their radulae along a clean glass surface and have been known to consume considerable quantities of paraffin and powdered carbon. In the field, the stomach contents of snails have revealed large quantities of sand and rock particles, detritus, any number of algal types, and occasional small animals, often still alive and active. There seems, therefore, to be little or no selectivity in what is ingested from any given surface. However, field studies to be discussed later suggest that each species has, at least under some conditions, definite preferences for certain types of substrates or algae.

The radula of these snails seems capable of tearing off quite large pieces of substrate material, and particles of considerable size have been found in their stomachs. Some of the smaller algae such as the filamentous *Cladophora* and the small monostromatous *Prasiola meridionalis* SETCHELL & GARDNER are frequently found almost entire in the stomach of *Littorina planaxis*. The structure of the radula and other mouth parts seems to be similar for both species, and, superficially at least, matches that of *L. littorea* as described by FRETTER & GRAHAM (1962, pp. 26-27).

What the winkles digest of what they take in is still uncertain. Undigested cells and tissue fragments are frequently found in the feces, supporting NORTH (1954) in his conclusion that their digestive efficiency is low, with organic matter assimilation about 7 percent of consumption. Cell wall material seems especially conspicuous, at least in the stomach, and was often useful in identifying the algae on which the snail had fed.

Littorina planaxis does not frequently come into contact with macroscopic algae; most of its range is well above the limits of such algal growth. There are areas, however, where it is found with all of the algae listed previously. In such areas, it shows a decided preference for a rock substrate. (For the purposes of this study the term "rock substrate" includes both microscopic and encrusting algal forms; "algal substrate" refers to macroscopic algae with other than an encrusting thallus; the substrate is the surface to which the snail is attached, and on which, presumably, it is feeding). One survey of the area near Pescadero Point showed only 2% of the *L. planaxis* on algal substrates; for another check under more favorable conditions (overcast sky), about 10% were observed on *Cladophora*. One individual had a considerable quantity of *Cladophora* in its stomach and a filament hanging out of its mouth, so feeding was almost certainly taking place in these cases. *Littorina planaxis* has also been collected on the thalli of what is either a high form of *Rhodoglossum affine* (the name used in this paper), or a juvenile form of *Gigartina cristata*. The stomachs of these snails contained a few fragments of tissue closely resembling scrapings from the alga but in such small quantities as to be an insignificant part of its diet. Snails collected from patches of *Prasiola meridionalis* on rocks covered with bird guano at Mussel Point proved to have large quantities of this alga, often whole thalli, in their stomachs and feces, in addition to quantities of a microscopic chlamydomonad. These are the only instances in the present study in which *L. planaxis* has been found to eat macroscopic algae under natural conditions. A

[2] Nomenclature of algae follows G. M. SMITH, 1944.

number of laboratory experiments suggest reasons for this behavior. In one experiment, thalli of *Endocladia, Rhodoglossum,* and *Porphyra* were finely chopped with a razor blade and spread on the wet bottoms of petri dishes; dishes with whole thalli, and a dish with a growth of "GATGOR" served as controls. A single freshly-collected *L. planaxis* was placed in each dish for 5 hours and then dissected. The snails consumed large quantities of the chopped pieces whole and also the "GATGOR," while the stomachs of the control winkles were empty, even when they were attached to the algae. In an algal preference test run in an aquarium kept damp by spray, the few *L. planaxis* that did not crawl to the top of the tank fed either on rock samples or on soft, decaying pieces of *Iridophycus flaccidum.*

There are several possible reasons why *Littorina planaxis* does not normally eat much macroscopic algae: (a) it is unable to "bite off" pieces of any but the softest or most finely divided algae; (b) it, for some reason, will not crawl on the "unstable" substrates provided by algae: (c) most macroscopic algae are somehow chemically disagreeable to it. Alternative (c) can be safely discarded, since *L. planaxis* showed no aversion to chopped algae. There is at present no evidence for or against reasons (a) and (b), although a brief examination of the mouth and radula showed no obvious differences from those of *L. scutulata,* which feeds much more on macroscopic algae.

In contrast with *Littorina planaxis, L. scutulata* both encounters more macroscopic algae and eats more of it. For instance, in the survey near Pescadero Point cited above, 47% of the *L. scutulata* in both areas were on algal substrates. There were marked preferences for certain species of algae. Of the 153 snails on algae, 72 were on *Cladophora,* 46 on *Pelvetia,* 20 on *Rhodoglossum,* and no more than 5 on any of the other species. Nor is this entirely a reflection of the relative abundance of the algae; *Endocladia,* the most common, had only 3 *L. scutulata* on it, and some of the others had fewer than their relative areas would suggest. Also, observations under more favorable conditions than those reflected in the above survey suggest that all these figures, especially for *Pelvetia,* are at times considerably higher. In other areas, *L. scutulata* is also found on *Fucus* and *Porphyra.* In addition, tidepool populations of *L. scutulata* have been observed scavenging on decaying algae such as *Gigartina corymbifera* and *Prionitus lanceolata* that had been left in the pools by very high tides. The stomachs of snails collected from these algae were stuffed with partially decomposed algal material.

Laboratory studies confirmed that *Littorina scutulata* will readily eat a variety of macroscopic algae. In addition to the *Cladophora* and *Pelvetia* mentioned above in which feeding was definitely observed, snails readily attacked *Ulva,* leaving only tattered shreds. In the preference tank *L. scutulata* was observed on all algae in the tank *(Pelvetia, Cladophora, Gigartina cristata, Endocladia, Rhodoglossum, Porphyra, Ulva, Iridophycus, Laminaria),* and all individuals dissected had macroscopic algal fragments in their stomachs (these were identified in the case of *Porphyra, Laminaria,* and *Ulva).*

The situation therefore seems to be similar to that noted by Castenholz (1961) for the effects of *Littorina scutulata* on diatom populations; the snails are able to prevent sparse populations from increasing but do not have much effect on well established colonies. The completely bare areas between algal growths in which periwinkles are so frequently found (Castenholz, *l. c.*) are probably kept bare by continual grazing, and the occasional presence of very young thalli in littorine stomachs supports this. In the study area at Pescadero Point, the *Pelvetia* is worn and indented, and in some places only the stubby remains of thalli can be found in the bottom of cracks, too tightly packed for the snails to reach. Even the *Endocladia* is undercut and trimmed back for about 1 cm above the rock surface in some areas bordering on bare rock. Whether these effects are due to the feeding activity of *Littorina* is not possible to say without lengthy observations and measurements, but considering the quantities of cell material found in stomachs, the depredations observed in the laboratory, and the number of snails involved, the effects of feeding are by no means insignificant. However, well established algal growths seem to hold their own successfully, at least for short periods. Two areas in the field, one with *Porphyra,* the other with *Cladophora* and *Ulva,* were caged with fiberglass netting and ¼ inch mesh galvanized screen into two compartments, one with 25 *L. scutulata,* the other empty as a control (a third compartment with 25 *L. planaxis* was added for the *Ulva, Cladophora* test). After two weeks, no effects were observed that could be directly attributed to the snails, although measurements were not very accurate. The effects on different algae probably vary considerably, judging from the varying quantities of algal material in the stomachs of snails feeding on different plants. *Porphyra* and *Rhodoglossum,* for example, were generally found in much smaller quantities than the softer *Pelvetia* and decaying algae, or the more easily ingested *Cladophora.*

While more work needs to be done on feeding preferences and the mechanisms affecting them, feeding effects, and seasonal and geographical variations in feeding habits, some conclusions can be drawn concerning the macroscopic algal foods of periwinkles. *Littorina planaxis*

generally eats only microscopic foods and those macroscopic algae small enough to be consumed entire or nearly so. The reasons for this are not clear, but may be related to the structure of the mouth or the preference for certain types of substrates. *Littorina scutulata* is frequently found eating macroscopic algae, especially *Cladophora, Pelvetia,* and other more easily ingested forms. The effects of this feeding are probably important in limiting the spread of new plants, and the effects on established thalli, while probably considerable in some instances, appear to vary greatly with the species of algae.

LITERATURE CITED

Castenholz, Richard W.
1961. The effect of grazing on marine littoral diatom populations. Ecology 42: 783 - 794

Foster, Michael S.
1964. Microscopic algal food of *Littorina planaxis* Philippi and *Littorina scutulata* Gould (Mollusca: Prosobranchiata). The Veliger 7 (2): 149 - 152 (1 October 1964)

Fretter, Vera, & Alastair Graham
1962. British prosobranch molluscs, their functional anatomy and ecology. London, Ray Soc. xvi + 755 pp.; 316 figs.

Newell, G. E.
1958. The behavior of *Littorina littorea* (L.) under natural conditions and its relation to position on the shore. Journ. Mar. Biol. Assoc. U.K., 37: 229 - 239

North, Wheeler J.
1954. Size distribution, erosive activities and gross metabolic efficiency of the marine intertidal snails, *Littorina planaxis* and *L. scutulata.* Biol. Bull. 106: 185 - 187

Ricketts, Edward F. & Jack Calvin
1962. Between Pacific tides. 3rd. ed., 2nd. rev. by Joel W. Hedgpeth. xiii 516 pp.; 135 text figs.; 46 plts.; Stanford Univ. Press, Stanford, California.

Smith, Gilbert M.
1944. Marine algae of the Monterey Peninsula. Stanford Univ. Press, 622 pps. Stanford, Calif.

Function of the Cephalic Tentacles in *Littorina planaxis* Philippi

(Gastropoda : Prosobranchiata)

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(10 Text figures)

In Fretter & Graham (1962, p. 14), the following description is given for part of the sensory apparatus in the snail *Littorina littorea:* "Toward its posterior end the head carries a pair of laterally placed tentacles. . . . At the base of each is a cushion-like bulge. . . . This is the eye stalk, and the dark spot on it is the eye. The tentacle, which is tactile and olfactory, is thus the seat of three major senses." The snail *Littorina planaxis* (Philippi, 1847), common along the California coast, has tentacles very similar to those described for *L. littorea.* Studies have revealed that the eye definitely is a light receptor and causes the animal to respond predictably to various light stimuli (Dieter Eckert, personal communication). However, the portion of the tentacle distal to the eye has not undergone extensive investigation, and tactile and olfactory capabilities of this part of the organ are undetermined. In April and May, 1964, studies were carried out at the Hopkins Marine Station of Stanford University, Pacific Grove, California, to determine the behavior and function of that part of the tentacle extending beyond the eye in *L. planaxis.*

The two cephalic tentacles are situated at the sides and slightly back of the large blunt snout. The organs are contractile, and when contracted they fit snugly at the sides of the mouth. Upon extension, they appear as delicate finger-like structures which exhibit movement patterns

that vary depending on the substrate or environmental condition the animal has encountered. They are innervated from the cerebral ganglion.

The tentacles are used by the animal as a main guide to its movements in the rocky areas which it so abundantly inhabits. The snail moves primarily during the lower temperatures at night and in the film of moisture provided by high tide and surf, with the tentacles generally remaining on the stony substrate and slowly moving from side to side. As the moisture decreases, or as obstacles are encountered, the organs begin an up and down pattern of movement, with the snail touching the substrate and immediately lifting the tentacle usually no more than one to one and a half millimeters. When the snail reaches an obstacle in its path, it undertakes a tactile survey of the impediment by extending the organs to their full tapering length and moving them about. When the animals are submerged, tentacular movement is usually restricted to a continuous motion from side to side, in contact with the substrate. In any circumstance, movements of the two tentacles may either be highly coordinated, as in horizontal swaying motions, or one tentacle may move completely independently of the other.

In order to determine more precisely the functions of the cephalic tentacles, I extirpated the organs in a group of *Littorina planaxis* and compared their responses with those in a group of normal snails under various conditions. It was necessary to anesthetize the animals prior to removing the tentacles. An aqueous solution of magnesium chloride isotonic with seawater proved to be superior to 1% propylene phenoxetol (Owen & Steedman, 1958), 1% chloral hydrate (Sivik, 1953), and 10 parts/million Sevin (Carriker & Blake, 1959) for the purposes of this investigation. Having adequately relaxed the animals, I could easily pull the head a good distance from the shell and snip off the entire tentacle distal to the eye with a pair of iridectomy scissors. The snails were then placed in normal seawater for recovery. In all instances, the operated snails exhibited activity similar to that of the normal snails. The wound appeared healed after two or three days, and operated animals placed in the field resumed normal activity and would occasionally be noted traveling three to five feet during a very moist night.

The following experiments and observations were carried out to compare the responses of normal snails with those of snails in which the tentacles had been removed.

GENERAL MOVEMENT AND RIGHTING

In the laboratory, the *Littorina planaxis* without cephalic tentacles did not exhibit striking locomotive inabilities. Glass dishes were used for all of the tests, and in practically every instance the animals that had been operated on travelled across the smooth surface at approximately the same speeds as the normal ones. When encountering obstacles, however, a definite difference in reaction was noted. A normal snail, with its tentacles exploring the substrate immediate in its path, would reach an object, touch it with the tentacles, and stop before bumping into it with the shell. On the other hand, a tentacleless snail would encounter the obstacle, bump into it with the shell, and continue for a time as if trying to push the object over. If the impediment happened to be another snail, the animals without tentacles could climb onto the shell, although observably slower than a normal animal.

To see if a lack of the tentacles produced an impairment to the ability for righting, I placed about 180 snails with tentacles and a like number without tentacles on their backs in glass bowls containing fresh seawater. They were

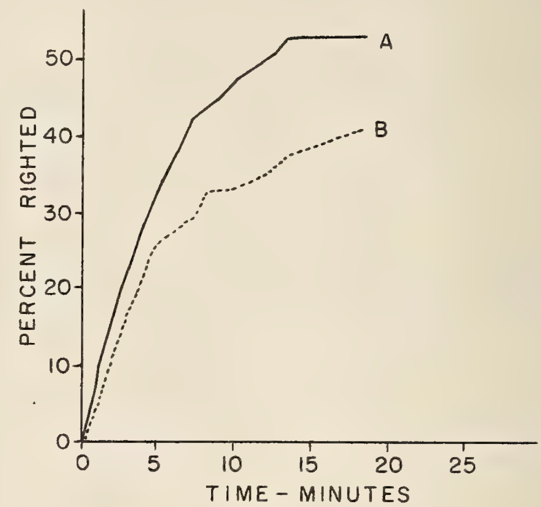

Figure 1: Rate of righting in *Littorina planaxis*. A - normal snails ($n = 180$); B - snails with tentacles removed ($n = 180$).

then timed from entry into the water until righted, at one minute intervals. The results, shown in Figure 1, indicate that of the animals which did complete the maneuver, the normal *Littorina planaxis* were slightly quicker. Further corroborating evidence that the snails are tactically dependent upon the organ for righting is that a fewer number of tentacleless animals than normal ones completed righting after trying.

RESPONSE TO WATERBORNE EXTRACTS OF *Acanthina spirata*

When the predaceous inter-tidal snail *Acanthina spirata* is introduced into a dish containing normal *Littorina planaxis*, a definite evacuation from the area of the larger snail will be detected within minutes. This response to the predator is induced through the effects of a waterborne chemical stimulus that issues from the *A. spirata*, probably produced in association with its mucus (Kenneth Tittle,

personal communication). To determine if the point of reception for this stimulus is the cephalic tentacle or if removal of the organ in any way affects the response, animals with and without tentacles were tested in the following manner.

From approximately the same area in the field, 100 *Littorina planaxis* were collected and the total population was anesthetized in isotonic magnesium chloride. After about an hour, the tentacles were removed from one half of the animals. After the operations, all of the snails were placed in fresh seawater for recovery. Three to four hours later the *Littorina* appeared totally recuperated and were then subjected to the tests. Two finger bowls were placed side by side, each containing 100 ml of seawater. In one bowl, five normal animals were placed and five animals lacking tentacles in the other one. Both groups were timed to determine the tendency to leave normal seawater. After 20 minutes, the snails were placed back into the center of the bowl, and 20 ml of seawater were added from a jar which had contained 30 *Acanthina spirata* in 180 ml for two days. Evacuation from the bowls was again timed and an accelerated departure from the water in both bowls was observed. To determine whether or not the animals were merely leaving the extract containing water because of having been replaced into water after

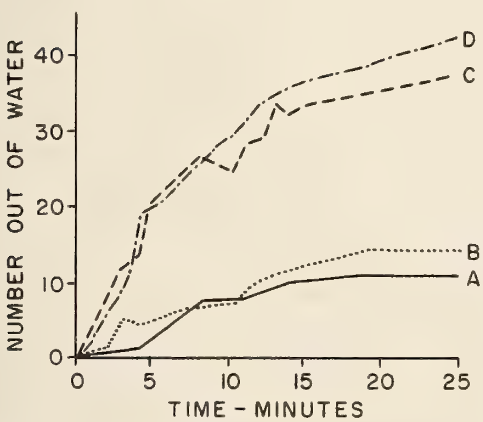

Figure 2: Response to waterborne extracts of *Acanthina spirata*. A - normal animals in untainted seawater; B - extirpated animals in untainted seawater; C - normal snails, response to *Acanthina spirata;* D - extirpated snails, response to *Acanthina spirata*. In each test n = 50

an initial departure, several tests were run with snails placed directly into the *A. spirata* water. Differences in response in the two instances were negligible. Identical runs were performed for the entire test population, using fresh seawater and *A. spirata* extract from the same jar each time.

Results of all trials are summarized in Figure 2, and show that the escape responses in normal *Littorina planaxis* and in the animals lacking tentacles were almost identical. It is therefore evident that the cephalic tentacles are not critically important as chemo-receptors in the detection of *Acanthina spirata* at a distance under water.

RESPONSE TO WATERBORNE EXTRACTS OF FEMALE *Littorina planaxis*

If water that has contained a group of female *Littorina planaxis* is added to water containing normal males of the same species, within a short period definite clustering and increased activity can be noted (Karin Rohe, personal

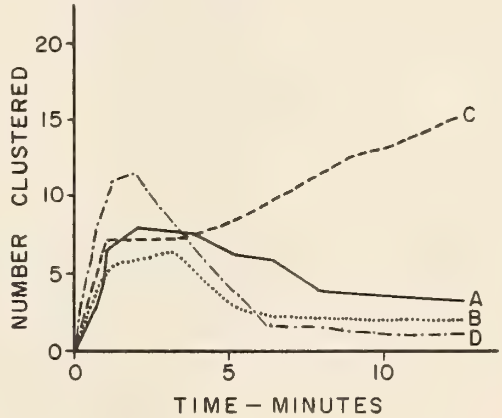

Figure 3: Response to waterborne extracts of female *Littorina planaxis;* A - normal males in untainted seawater; B - extirpated males in untainted seawater; C - normal males, response to female extract; D - extirpated males, response to female extract. In each test, n = 50.

communication). To determine if the cephalic tentacles were pertinent in detecting this waterborne molluscan aphrodisiac, tests similar to the *Acanthina spirata* experiment were set up, using the same general procedure as described. In one bowl containing normal seawater were placed five normal males; in a second bowl, also containing seawater, five males lacking tentacles were placed. At one minute intervals clustering tendencies were timed by recording the number of snails in contact with other animals, either side by side or one on top of another. Following this, 20 ml of seawater, taken from a jar containing approximately 200 ml of water in which 25 female snails had been kept for four hours, was added to each bowl. Again the number of clustered animals versus time

was noted. Tests were run on 50 normal and 50 operated individuals.

Results of all tests are summarized in Figure 3. All snails, both experimentals and controls, showed some initial tendency to pair and thus form clusters. However, this tendency is short lived except in the normal males exposed to female extract. Perhaps the reason the response is not sustained in extirpated males is that once the animal has climbed onto the back of another snail, he lacks the probing equipment necessary to determine the sex of his partner or to assume the correct position. The results again suggest that the tentacles do not play a role in chemo-reception, though they appear necessary for definite sex recognition on contact.

RESPONSE TO MUCUS TRAILS

It has been observed (Allan Miyamoto, personal communication) that *Littorina planaxis* tend to follow mucus trails across the rocks. A series of experiments were developed to determine the role of the tentacles in such behavior. Because the tentacles tactically precede the animal, it appears that these organs would be apt for detection of trails.

By cutting off the foot of a *Littorina planaxis* and dabbing the structure on a glass plate, an artificial mucus path can be applied as depicted by the dotted lines in Figure 4a. Two normal male *L. planaxis* and two males lacking

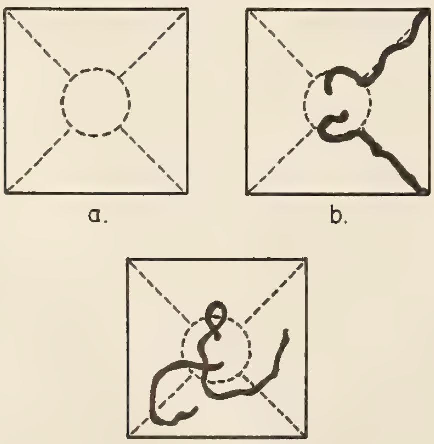

Figure 4: Response to mucus trails. a - pattern of mucus applied on all test plates. b - example of movement recorded for two normal *Littorina planaxis;* c - example of movement recorded for two *Littorina planaxis* lacking tentacles.

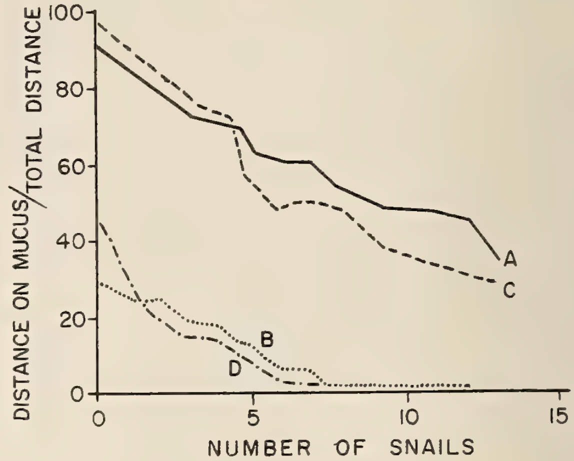

Figure 5: Relative tendency of male *Littorina planaxis* to follow mucus trails from male and female *Littorina planaxis;* A - normal male, response to female mucus; B - extirpated male, response to female mucus; C - normal male, response to male mucus; D - extirpated male, response to male mucus. In all tests, n = 10.

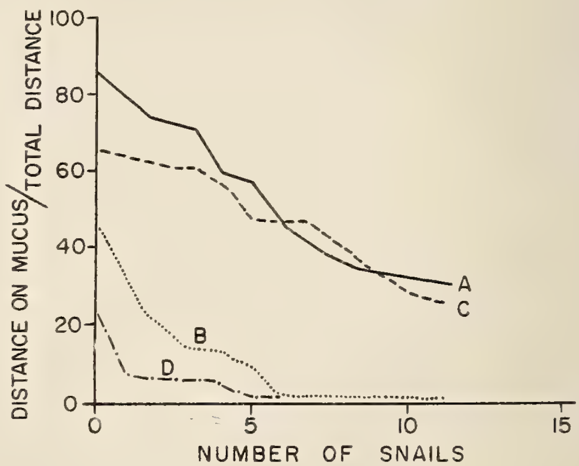

Figure 6: Relative tendency of female *Littorina planaxis* to follow mucus trails from male and female *Littorina planaxis;* A - normal female, response to male mucus (n = 8); B - extirpated female, response to male mucus (n = 8); C - normal female, response to female mucus (n = 6); D - extirpated female, response to female mucus (n = 6).

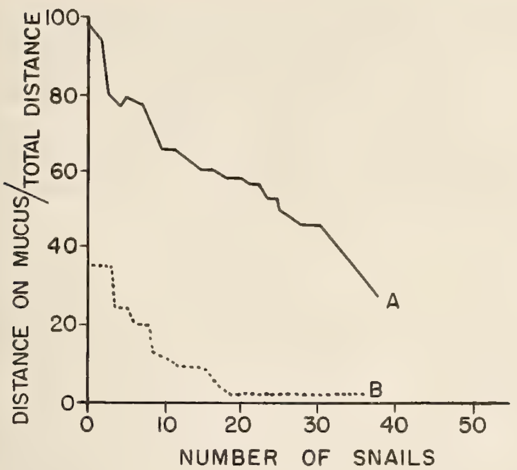

Figure 7: Tendency to follow mucus trails; composite results from Figures 5 and 6; A - normal *Littorina planaxis,* response to *Littorina planaxis* mucus; B - extirpated *Littorina planaxis,* response to *Littorina planaxis* mucus.

tentacles were placed respectively in the centers of two plates 6 by 6 inches square, each plate bearing mucus trails from female feet. The plates were then taken into a dark room and sprayed lightly and equally with seawater. After 15 minutes, the snails were removed and the glass plates were immersed in a dilute suspension of India ink in seawater to mark the paths of the animals during their movements in the dark, a technique designed by Dieter Eckert (personal communication, 1964). Experiments were carried out using each sex as a source of mucus and each sex as a test animal. Two specific examples of typical results obtained appear in Figures 4b, c.

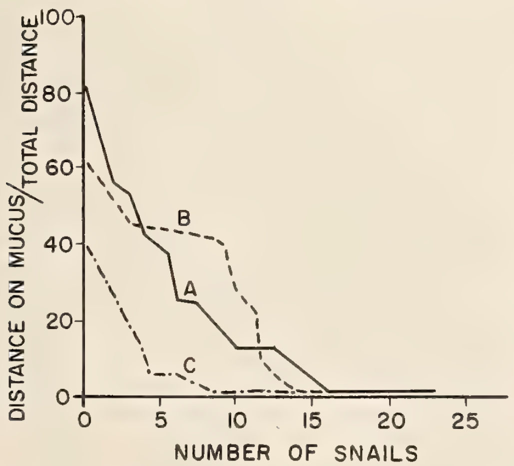

Figure 8: Relative tendency of normal *Littorina planaxis* to follow mucus trails of other inter-tidal snails; A - mucus of *Acmaea digitalis* (n = 16); B - mucus of *Acanthina spirata* (n = 12); C - mucus of *Tegula funebralis* (n = 8).

Figures 5, 6, and 7 summarize the results of all tests performed. They clearly indicate that the animals do employ their tentacles in following *Littorina planaxis* mucus trails, and that they follow trails regardless of the sex of the animal making the trail. This result suggested that perhaps the tentacles are sensitive to any mucus or material that noticeably changes the surface texture of the substrate. Therefore the mucus from several other intertidal molluscs was employed, using the same method as described. The results for this set of investigations is shown in Figure 8. In most cases it seems that the mucus from species living in close proximity to the *L. planaxis* populations exhibit properties close enough to the *Littorina* mucus to elicit at least partial following. Artificial trails made with methyl cellulose and granular mucin were tried, but neither provided positive results.

FIELD OBSERVATIONS

For observations concerning activities of both normal and tentacleless animals while in regular field conditions, 100 males and 100 females were taken from a large rock surface. All were anesthetized using magnesium chloride, the tentacles were removed from one half of the males and one half of the females, the animals were marked, and all were placed back on the rock in a large fenced area from which all other *Littorina* were removed. Reg-

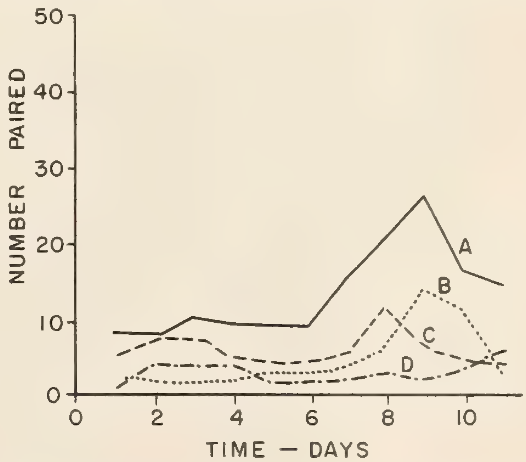

Figure 9: Pairing frequencies for all four combinations of normal males and females and males and females lacking tentacles. In the field, animals were considered paired when the male was on the back of a female; A - normal males on normal females; B - extirpated males on normal females; C - normal males on extirpated females; D - extirpated males on extirpated females.

ular daily observations were recorded pertaining to pairing, clustering, and single activity for 12 days. Figure 9 shows pairing frequencies for all four combinations of normal males and females and extirpated males and females. Field observations suggest that the males locate the females for copulation. Therefore Figure 10 shows the comparative pairing, with any type female, of normal and extirpated males. Both of these results indicate that the animals without tentacles, especially males, are less able to locate female *Littorina* for pairing. This result follows

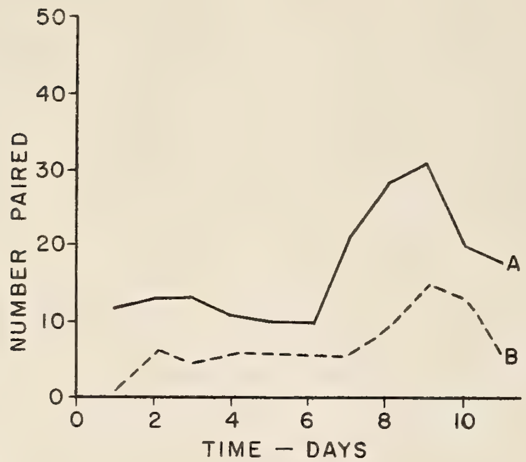

Figure 10: Pairing frequencies for normal and extirpated males, based on data of Figure 9; A - normal males; B - extirpated males.

the conclusions drawn from the mucus trail experiments, in that the tentacles are pertinent for following another mucus pathway and for sex recognition on contact.

RESPONSES AFTER EXTIRPATION OF A SINGLE TENTACLE

After removing one tentacle and placing the animal on a clean glass plate, the path assumed by the snail while in the dark was determined by again using the carbon bath. Such experiments did not give clear cut results, but merely hinted at tendencies. Twenty-four snails were tested, 12 with the left tentacle removed and 12 with the right taken off. The results were that 8 of the animals lacking a tentacle on the left side exhibited circus movements to the right, and 6 snails without a tentacle on the right side moved in circus motions to the left. Perhaps the nature of the substrate did not lend to more consistent results, but circus movements are suggested, indicating a dependency on tactile assurance.

SUMMARY

1. The cephalic tentacles of *Littorina planaxis* are not critical to general movement, but are used, while the snail moves, for tactile surveillance, and they enable the animal to perform more easily such maneuvers as righting.
2. Removal of the tentacles does not impair the ability to detect diffusible substances from the predaceous snail *Acanthina spirata* or from female *Littorina planaxis*.
3. The tentacles appear necessary for sex recognition on contact.
4. The tentacles are employed in following mucus trails on the substrate. The trails of other *Littorina planaxis* are followed more consistently than are trails laid down by other species of mollusks.

ACKNOWLEDGMENTS

I am happy to acknowledge the advice of Dr. Donald P. Abbott.

LITERATURE CITED

Carriker, Melbourne Romaine, & John W. Blake
1959. A method for full relaxation of muricids. Nautilus 73 (1): 16 - 21

Fretter, Vera, & Alastair Graham
1962. British prosobranch molluscs, their functional anatomy and ecology. London, Ray Soc. xvi + 755 pp.; 316 figs.

Owen, G., & H.F. Steedman
1958. Preservation of molluscs. Proc. Malacol. Soc. London 33 (3): 101 - 103

Sivik, Frank P.
1953. A comparison of the effects of various relaxing agents on slugs. Turtox News 31 (4): 66 - 68

Microscopic Algal Food of
Littorina planaxis Philippi and *Littorina scutulata* Gould

(Gastropoda : Prosobranchiata)

BY

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Littorina planaxis and *L. scutulata* are commonly observed inhabiting the granitic upper littoral and supralittoral areas generally devoid of macroscopic algae. This study was undertaken to determine what microscopic algal types the animals were eating in these seemingly bare areas and to get an idea of the effects of this feeding on algal growth.

The study is conveniently divided into two parts: 1. Identification; 2. Determination of standing crop of microscopic algae and the effect of the snails grazing upon it.

1. Identification

METHODS

Rock specimens were removed from areas inhabited by the animals (especially *Littorina planaxis*) in the 6 to 8 foot range above mean zero tide. Their surfaces, crevices, and cracks were scraped into sterile sea water and then plated on an agar culture medium.

The media used were of two basic types. Medium 1 was made up of 2% agar in sterile sea water plus 10^{-3} molar Na_2HPO_4 and 10^{-3} molar NH_4NO_3. A soil extract (see Pringsheim, 1946) was prepared by mixing crushed granite with dark soil in 1 to 1 proportions. To this mixture was added 2 parts sea water and the soil-granite and water were heated at 90° C for one hour. The mixture was then filtered and the brownish liquid filtrate was added to the culture medium, 1 part soil extract to 10 parts agar plus sea water.

Medium 2 was identical with medium 1 except that NH_4NO_3 was omitted and 10^{-6} molar Na_2MoO_4 added. This medium was used to encourage the growth of possible nitrogen fixing blue-green algae present.

In addition to the above media, two more were made, one using medium 1 with a salt concentration in the sea water of four times normal, and another using medium 1 with *Littorina planaxis* mucus and feces spread over the surface. Both were prepared to approximate more closely the natural habitat of the algae.

Many snail shells, especially those of *Littorina planaxis,* have a very green color and are often deeply eroded and pitted. In addition, snails are normally observed crawling on one another. It was thought that the green may be a source of microscopic algal food, and perhaps the cause of the erosion. Therefore, the outer layer of a green shell and a brown eroded shell were scraped and plated on medium 1.

Snails of both species were collected after high high water while moving, dissected, and their stomach contents plated on both media 1 and 2 to culture any undigested pieces of algae.

Lastly, since the animals are splashed regularly during high tides, some sea foam was collected and plated to identify possible algal food sources not living directly in or on the granite rocks.

The cultures were placed upside down in front of a north window which had been covered with tissue paper to prevent overheating from direct sunlight.

In addition to culturing, rock specimens, shells, and stomach contents were examined directly in the laboratory.

RESULTS

The first growth in culture consisted of bacteria, but after ten days diatoms were very conspicuous, especially in medium 1 culture from rock surfaces. After 15 days most of the algae to be described began to grow, and three were subcultured.

The alga giving the common green coloration to round rocks in tide pools and to granite surfaces above tide pools in the high intertidal was identified as the chlorophyte, *Spongomorpha coalita* (Collins, 1909). This form has the general appearance of the description given by Smith (1944), but is a much smaller, juvenile stage. It was found much higher than Smith states, growing well within the 6 to 8 foot range in small cracks in the rock surface and

on the surface itself. It was also grown in stomach content cultures of both species and in sea foam culture. The growth in the latter was probably from fragments of alga washed from the rock surfaces.

The green alga growing in the outer layers of the shell of *Littorina planaxis* was identified as *Endocladia testarum* (KYLIN, 1935). Previously, this alga had been described in the United States on the east coast only, inhabiting dead mollusk shells (see THIVY, 1943). Growth of this alga was also obtained from stomach contents of both species. When the outer layers of eroded shells were dissolved with HCl and the underlying material scraped off and examined, the alga was very prevalent, especially the massive, spherical thallus of overlapping, fused filaments. Since *Endocladia testarum* grew well from scrapings of a brown eroded shell with no visible surface green, it may be the agent responsible for the shell erosion.

Prominent among the blue-green algae found were *Plectonema terebrans* (BORNET & FLAHAULT, 1889), *Calothrix pilosa* (HARVEY, 1858), and *Calothrix crustacea* (BORNET & THURET, 1878). These algae fit the general description given by UMEZAKI (1961). *Plectonema terebrans* differs from UMEZAKI's description, being found here in shells of live *Littorina planaxis* and on the granite rocks in close association with the other blue-green algae and with *Spongomorpha coalita* previously mentioned. It could also be responsible for some of the erosion of shells, since it is a shell boring form. All three of these blue-green algae were found from cultured stomach contents, and *P. terebrans* was found in cultured sea foam (probably washed from rocks). *Calothrix pilosa* was very abundant in the cultured stomach contents of *L. planaxis*. Generally, the blue-green algae did as well in medium 2 as medium 1, so the presence of nitrogen fixing forms is possible.

Dermocarpa sp. (CROUAN, 1858. See SMITH, 1950) and *Spirulina* sp. (TURPIN, 1892. See UMEZAKI, 1961), two other blue-green algae, were found in limited quantities. The *Spirulina* was found in association with *Plectonema terebrans* on rock surfaces, and *Dermocarpa* was found growing on *Rhodochorton Rothii* (NAGELI, 1862) filaments in the field only.

Rhodochorton Rothii was the only red alga found, commonly in crevices receiving very little sunlight. *Littorina planaxis* is often observed in these crevices and some pieces of *R. Rothii* were found in their stomach contents, although none grew in culture, probably because of its unusually cold, damp habitat. This alga fits the description given by SMITH (1944) except for its growing in crevices.

Diatoms and unicellular green and blue-green algae were found in most cultures but no attempt was made to identify them. The diatoms were especially abundant both in rock surface cultures and stomach content cultures of both species, and seem to constitute one of the primary food sources of the snails. (see CASTENHOLZ, 1961).

2. Determination of Standing Crop and *Littorina* Grazing Effects

METHODS

a. Chlorophyll Content: In an effort to determine the standing crop of all the microscopic algae in the 6 to 8 foot range, areas of rock were chipped from the surface with hammer and chisel. The chlorophyll was extracted with methyl alcohol and its absorption spectra determined. These spectra were compared with the absorptoin spectrum of a similar size piece of *Ulva*.

The rock samples extracted were 5 cm by 5 cm square and from 1 to 10 mm deep, depending on the depth of the green coloration beneath the surface. Because this depth varied, all calculations were based on surface area and not volume.

The rock samples were crushed with a mortar and pestle, placed in dark screw cap bottles, and covered with 50 ml absolute alcohol per $25 cm^2$ of rock surface. Acetone and ethyl alcohol were tried but did not effect complete extraction. The bottles were placed in a refrigerator for 29 hours, contents filtered through No. 1 filter paper, and immediately analyzed on a Beckman Model DUR spectrophotometer at wave-lengths from 430 to 680 millimicrons.

Samples of *Ulva* were cut into 1 cm squares and extracted in a similar manner without grinding. The values obtained were modified by multiplying by 25 to give values for $25 cm^2$ *Ulva*/50 ml alcohol.

To estimate the algal content of the *Littorina planaxis* shells, snails were removed and their shells crushed and extracted as above. The absorption spectrum was corrected to $25 cm^2$ shell surface / 50 ml alcohol. The shell surface area estimations are described under Photosynthetic Rate.

b. Photosynthetic Rate: Rock samples were removed intact from outcroppings and a $25 cm^2$ surface area exposed, the rest of the rock covered with aluminum foil to prevent light from entering. The rocks were placed in one liter jars filled with sea water of a known O_2 concentration, and placed in the sun for ½ hour. The rocks were then removed and the water analyzed by the Winkler method to determine O_2 increase. From this, carbon production was calculated.

Ulva's photosynthetic rate was previously determined (see under Final Determination of Standing Crop).

The photosynthetic rate of the algae on the snail shells (*Littorina planaxis*) was determined by cracking the shells to remove the snails and putting the shells in sea water in direct sunlight. O_2 increase was again measured by the

Winkler method. Snail shell surface area was calculated by approximating with $1/\pi$ of $\pi R\sqrt{R^2+H^2}$, the formula for the area of the curved surface of a right circular cone. R here is the distance across the opercular opening and H the height of the shell from the bottom of the opercular opening to the top of the spire (see NORTH, 1954).

c. Respiration Rate: Only the respiration rate for the algae on a 25 cm^2 granite surface was measured. This was accomplished by chipping a rock to the desired dimensions and putting it in sea water in the dark for 12 hours. O_2 concentration before and after was measured by the Winkler method and O_2 decrease calculated.

RESULTS

a. Chlorophyll Content: The absorption spectra of methanol extracts from an average of three 25 cm^2 rock surfaces, three *Ulva* samples, and four crushed shells were determined. Since chlorophyll (a) is present in all the algae found, this was used as a standard of comparison.

Using Strickland and Parson's method (1960), chlorophyll (a) content was determined by the formula

$$Cla = 15.6\ E_{665} - 2.0\ E_{645} - 0.8\ E_{630}$$
$$= \text{mg chlorophyll (a) / liter of solvent}$$

This formula measures absorption with a 1 cm cell, with E being extinction or absorption. Values obtained from samples were first multiplied to give 25 cm^2 surface area and then multiplied by the number of milliliters used in extraction over 1000 to give Cl(a) present per liter of solvent. This figure was then multiplied by 400 to convert to m^2 of surface area.

The value for the algae on the granite surfaces in the 6 to 8 foot tidal range (av. of 3 samples):

$$= .043 \text{ g Cl (a)} / m^2$$

This figure is approximate because methanol does not extract the main pigments in the blue-green algae.

Ulva chlorophyll (a) content using the same formula:

$$= .081 \text{ g Cl(a)} / m^2 \text{ (av. of 3 samples)}$$

Shell chlorophyll (a) content was not calculated because after 29 hours the shells were not completely extracted. It is significant that even with incomplete extraction the shells had a higher pigment content than either the *Ulva* or the rock.

b. Photosynthetic Rate: Rock surfaces (av. of 4 tests):

$$= 7.8 \text{ ml } O_2/25\ cm^2/\text{day}$$
$$= 3120 \text{ ml } O_2/m^2/\text{day (assuming 12 hours of light in a day)}$$

Ulva previously determined for Hopkins Marine Station (see BLINKS, 1955):

$$= 3 - 7.2 \text{ g carbon} / m^2 / \text{day}$$

Algae on shells *(Littorina planaxis)*:

$$= .981 \text{ g carbon} / m^2 / \text{day}$$

c. Respiration Rate: Algae on rock surfaces (av. of 3 tests):

$$= 246.8 \text{ ml } O_2 / m^2 / \text{day}$$

Final Determination of Standing Crop

Since the photosynthetic rate of the algae on the granite surfaces is about half that of *Ulva*'s minimum value, and the chlorophyll (a) content of the algae on the granite surfaces is approximately half that of an equal surface of *Ulva*, then it is assumed that chlorophyll (a) content and standing crop are related and that the relation for *Ulva* is proportional to that of the algae on the granite surfaces. If this assumption can be made, then dividing *Ulva*'s chlorophyll (a) content into that of the rock:

$$.043 \div .081 = .53$$

Standing crop of *Ulva* for Hopkins Marine Station (BLINKS, 1955).

$$= 70 \text{ g carbon} / m^2$$

Then the standing crop of algae on the granite surfaces

$$= (70)\ (.53) = 37 \text{ g carbon} / m^2$$

Dividing standing crop by production rate we get time for the algal crop on the rocks:

$$= 37 \div 1.66 = 22.3 \text{ days.}$$

A chart summarizing the results of standing crop determinations is presented in Table I.

Effects of Grazing

METHODS

For this determination a flat surface was selected at the 6 foot tide level. Six baskets of 15 cm by 15 cm by 5 cm size were fastened to the rock by bolts driven into the surface. The area received abundant splash and spray during high tides and was inhabited by snails of both species, but primarily *Littorina planaxis*.

Ten snails *(Littorina planaxis)* with a volume of .27 cc / snail were introduced into each of three of the baskets while the other three baskets were kept empty.

After 25 days the baskets and snails were removed and 10 cm^2 sections of granite were chipped from the center of each basket-covered area. The sections were analyzed as in previous chlorophyll (a) determinations to ascertain any differences in pigment content which could be used as a measure of algal food consumed.

RESULTS

The absorption spectra of extracts of grazed and ungrazed surfaces were determined, but since chlorophyll (a) content was not known before the test, its calculation would not be meaningful.

For a general measure, subtracting the absorption values for grazed and ungrazed surfaces at the peaks gave

TABLE I: Summary of Standing Crop Determinations

Type of Surface	Chlorophyll (a) content grams/m²	Respiration rate ml O_2/m^2/day	Production and Crop: Photosynthetic rate grams carbon/m^2/day	Standing crop grams carbon/ m^2	Time for crop days
Ulva	.081	-------	3 to 7.2	70	10 to 23
Algae on Granite Surfaces	.043	286.8	1.66	37	22.3
Algae on *Littorina planaxis* Shells	-------	-------	.981	-------	-------

a value of from 6% to 10%. Therefore, 10 snails with a volume of 2.7 cc grazing on a 225 cm² surface of granite reduced the pigment content by approximately 8% when compared with an ungrazed surface over a period of 25 days. This figure is only approximate, since a standard deviation cannot be calculated.

SUMMARY

1. The following algae were identified in the habitat of *Littorina planaxis* and *Littorina scutulata* (* denotes positive identification as food):

**Spongomorpha coalita*
**Endocladia testarum* (on shells)
**Plectonema terebrans*
**Calothrix pilosa*
**Calothrix crustacea*
**Rhodochorton Rothii*
Dermocarpa sp.
Spirulina sp.
*Unicellular green and blue-green algae
*Diatoms

2. The standing crop of microscopic algae on granite surfaces is about half that of *Ulva*. The pigment content of the algae on the shells of *Littorina planaxis* is much greater than that of a rock or *Ulva* surface of similar size.

3. In 25 days, ten snails reduce the algal pigment content of a 225 cm² granite surface by approximately 8% when compared with an ungrazed surface of similar size.

NOTES & NEWS

ERRATA

BY

WALTER O. CERNOHORSKY
Vatukoula - Fiji Islands

In "The Cypraeidae of Fiji," published in The Veliger 6 (4): 177 - 201, the following passages should be emended:

p. 180 - bottom, for: Synonyms are shown in brackets [ ] read: generic and subspecific terms are shown in brackets [ ]

p. 182 - No. 4, for: *nomen nudum* read: non binominal

p. 188 - No. 25, for: *Monetaria annulus sosokoana* Ladd, read: *Cypraea* (*Monetaria*) *annulus sosokoana* Ladd

p. 189, - No. 29, for: *Cypraea erosaria agassizi* Ladd, read: *Cypraea* (*Erosaria*) *agassizi* Ladd

p. 192: Explanations for figures 15 and 15 a belong to plate 23, not plate 24

p. 193 - No. 39, for: *Erronea cauricathema* Iredale, read: *Erronea caurica thema* Iredale

p. 193 - No. 41: the year 1938 should be placed after Schilder & Schilder

p. 194 - No. 44, for: *Cypraea lutea* Gronow, 1781, read: *Cypraea lutea* Gmelin, 1791.

p. 198 - No. 55, for: *Bistolida stolida trakau* Steadman & Cotton, read: *Bistolida stolida thakau* Steadman & Cotton

p. 200: Opinion 261 of I.C.Z.N rejects Gronovius' Zoophylacium Gronovianum for nomenclatorial purposes. Gronovius' *Amphiperas* must be replaced by *Ovula* Bruguière, 1789, and the heading Amphiperatidae should be changed to Ovulidae.

No. 2: *Ovulum angulosum* Lamarck 1822, should be emended to *Ovula angulosa* Lamarck 1822, as *Ovulum* was not established by Lamarck, but by Sowerby in 1828

LITERATURE CITED

Blinks, Lawrence R.

1955. Photosynthesis and productivity of littoral marine algae. Sears Found. Journ. Marine Res. 14 (4) : 363 - 373

Castenholz, Richard W.

1961. The effect of grazing on marine littoral diatom populations. Ecology 42: 783 - 794

North, Wheeler J.

1954. Size distribution, erosive activities and gross metabolic efficiency of the marine intertidal snails, *Littorina planaxis* and *L. scutulata*. Biol. Bull. 106: 185 - 187

Pringsheim, E. G.

1946. Pure cultures of algae, their preparation and maintenance. Cambridge Univ. Press, Cambridge. 119 pp.

Smith, Gilbert M.

1944. Marine algae of the Monterey Peninsula. Stanford Univ. Press, 622 pps. Stanford, Calif.

1950. The fresh water algae of the United States. New York, McGraw-Hill Book Co., Inc. 719 pps.

Strickland, J.D.H., & T. R Parsons

1960. A manual of sea water analysis. Fish. Res. Brd. of Canada, Bul. 125. 185 pp.

Thivy, F.

1943. New records of some marine Chaetophoraceae and Chaetosphaeridiaceae for North America. Biol. Bull. 85/86: 244 -264

Umezaki, I.

1961. The marine blue-green algae of Japan. Mem. Coll. Agric., Kyoto Univ. no. 83. 149 pp.

The term 'Pediculariidae' should be placed below No. 9

No. 14, for: *Cypraea grando* Gaskoin, 1848
read: *Cypraea grando* Gaskoin, 1849

No. 16, for: *Trivia tremeza* Duclos, 1833,
read: *Cypraea tremeza* Duclos, 1833

On plate 26, the ventral view of figure 52 is mounted inversely.

The currently used subspecific terms as shown in the synonymy were not accompanied by original reference citations and thus did not indicate the taxonomic rank under which they were originally established by their respective authors. The following taxa were originally designated as full species by their authors:
Cypraea retifera Menke (No. 7); *C. caledonica* Crosse (No. 14); *C. propinqua* Garrett (No. 17); *C. noumeensis* Marie (No. 25); *C. barthelemyi* Bernardi (No. 26); *C. helenae* Roberts (No. 28); *C. scarabaeus* Bory (No. 31); *Purperosa facifer* Iredale (No. 34); *Trivia consobrina* Garrett (No. 35); *C. bregeriana* Crosse (No. 37); *C. coerulescens* Schröter (No. 38); *C. melvilli* Hidalgo (No. 40); *C. candida* Pease (No. 43); *C. vittata* Deshayes (No. 45); *C. unifasciata* Mighels (No. 46); *C. rhinoceros* Souverbie (No. 49); *C. subfasciata* Link (No. 51); *C. crossei* Marie (No. 55).

BOOKS, PERIODICALS, PAMPHLETS

Obervations on some Structural Features of the Pelecypod Shell

by J. J. Oberling, Mitteilungen d. Naturforschenden Gesellschaft in Bern, N. F., Volume 20, pages 1 to 60, 6 plates and 3 text figures.

This paper is a condensed version of a Ph. D. dissertation (1955) on the detailed structure of the pelecypod shell, based on studies pursued in the Department of Paleontology of the University of California (Berkeley). A short paper announcing some of the significant general results was published in 1955 (Journ. Wash. Acad. Sci., vol. 45, pp. 128 - 130). Oberling has shown that traditional concepts of pelecypod shell structure (still perpetuated in many texts) are oversimplified and largely erroneous. Instead of "nacreous" and "prismatic layers" or "ostracum" and "hypostracum" and similar terminologies, he has proposed a new terminology, based on the largely overlooked fact that where muscles (adductors, pedal, pallial line area of mantle, etc.) are attached, a distinctive shell deposit is formed. Deposits in these areas are termed myostracum, with that formed at the pallial line (pallial myostracum) forming an exceedingly important zone of reference. Three principal layers are recognized within the rest of the calcareous shell, from interior out, these are: **endostracum** (internal to pallial myostracum); **mesostracum**; and **ectostracum** (external calcareous layer). The presentation is marred by carelessness.

JWD

Selected Shells of the World Illustrated in Colour - (II)

by Tokio Shikama, Geological Institute, Yokohama National University, Japan. 212 pp., 70 color plates, 243 text figures; May, 1964. M. Fukuda, publ., Tokyo. Price $25.00, incl. postage.

This is the second and final volume of the outstanding publication reviewed in our previous issue (July 1964); it completes the systematic pictorial sampling of all groups of mollusks which was begun in Volume I. The new volume concludes the illustrations of typical marine gastropods and continues with land snails, pelecypods, scaphopods and cephalopods. The format is the same as in the earlier volume and the colored photographs are just as spectacular. Since this beautiful book illustrates worldwide species of most of the major mollusk families, it would be of value to collectors in any land even though the text is in Japanese.

There is an excellent index, in Roman type, of the scientific names of the shells, and each plate is explained in English as well as in Japanese on a very convenient translucent overleaf. A noteworthy feature of the new book, of special interest to philatelists as well as to malacologists, is a full page illustrating shell-decorated postage stamps from several countries.

JMC

Contributions to the Knowledge of the South African Marine Mollusca. Part V. Lamellibranchiata.

by K. H. Barnard. Annals of the South African Museum, Volume 47, part 3, pp. 361 - 593, 39 text figures; March, 1964.

This paper deals with about 331 identified species and subspecies (and a number of others only tentatively identified or identified only as to genus) of marine pelecypods from South Africa. Of these, 21 are described as new species and two new names are proposed. The species are arranged in 50 families and 126 genera. Families represented by the largest number of species are the Veneridae (13 genera, 32 species), Mactridae (5 genera, 22 species), and Tellinidae (4 genera, 19 species).

As might be expected, most of the species live only in the South African and adjacent regions but some wide

ranging forms also occur there. Only a few species are believed to be closely related to east American species. Other than widespread species such as *Saxicava arctica,* none of the species in this faunal assemblage occurs in west American waters, but attention is called by the author to the similarity of *Thyasira investigatoris* (E. A. SMITH) to *T. excavata* DALL which was described from off California.

An interesting discovery reported by Barnard is that of a small pecten (*Cyclopecten incubans*) which incubates its young.

Arca gradata BRODERIP & SOWERBY and *Arca domingensis* LAMARCK are included in the synonymy of *Arca (Acar) plicata* (CHEMNITZ) DILLWYN. However, most west American authors consider *A. gradata* and *A. domingensis* to be distinct forms, the former living in tropical and subtropical waters in the eastern Pacific and the latter in the western Atlantic.

The synonymy, illustrations (made from line drawings), discussions, keys to many of the species, and bibliography, all combine to make this a very useful and important reference work for anyone interested in the pelecypods of South Africa.

LGH

A Quantitative Analysis of Molluscan Collections from Isla Espíritu Santo, Baja California, Mexico

by A. MYRA KEEN. Proceedings of the California Academy of Sciences, Fourth Ser., Vol. 30, No. 9, pages 175 to 206, 4 figures. July 1, 1964

The analysis reported herein is based on comparatively large samples of material collected on three separate occasions. Analyses are presented in clear tables. In the conclusions drawn, the author points up the value of this type of study because of the need of caution in interpretation of paleontological material that is brought out.

RS

Scaphopoda and Gastropoda from Depths Exceeding 6000 Meters

by JORGEN KNUDSEN. Galathea Report, Volume 7, pages 125 to 136, 10 text figures. 15 February 1964.

Six new species from the profound depths of the Sunda and Kermadec Trenches are described: 1 Scaphopod — *Siphonodentalium galatheae;* 2 trochids — *Guttula galatheae* and *Trenchia wolffi;* 1 aclidid — *Aclis kermadecensis;* and 1 melanellid — *Melanella hadalis.* It is to be noted, also, that *Trenchia* is a new genus with *T. wolffi* as the type species by monotypy.

RS

On Brazilian Supralittoral and Brackish Water Snails

by EVELINE & ERNST MARCUS. Bol. Inst. Ocenograf. Vol. 13, No. 2, pages 41 to 52, 1 plate. 1963

This relatively short paper records a wealth of information on the development, morphological characters and geographical distribution of several species of gastropods occurring in the habitats mentioned in the title.

RS

Studies on the Venom of the Marine Snail *Conus californicus*

by JOHN A. WHYSNER & PAUL R. SAUNDERS. Toxicon, Volume 1, pages 113 to 122, 1 text figure. 1963.

This appears to be a careful pharmacological study of the venom of the California cone. The authors indicate that the venom, if injected into mice, may kill the subject, while moderate doses in rabbits cause a reduction in the blood pressure. It may be well to point out that to date no records of poisoning of human beings by this cone have become known.

RS

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(signed) R. Stohler, Editor.

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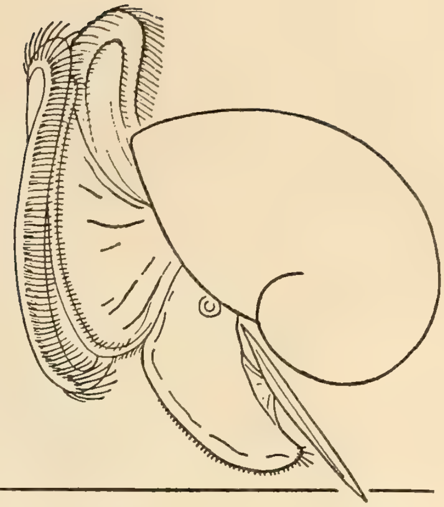

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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION, Subdivision,** SECTION,
SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).
New Taxa

Systematics of the Hawaiian *Littorina* Ferussac

(Mollusca; Gastropoda)

BY

JEANNETTE A. WHIPPLE

Duke University, Durham, North Carolina[1]

(Plates 25 and 26; 4 Text figures)

INTRODUCTION

The gastropod genus *Littorina* Ferussac is represented in the Hawaiian Islands by five species. Two of these species, *Littorina pintado* (Wood) and *Littorina picta* Philippi are the predominant animals in the supratidal region of the rocky coast of Oahu. A third species, *Littorina scabra* (Linnaeus), occurs on protected shores such as are found along breakwaters and harbors and in some areas, on the roots of mangrove trees. The fourth species, *Littorina undulata* Gray, is relatively rare. An additional unidentified species is represented by only one specimen.

On Oahu, *Littorina pintado* and *L. picta* are usually sympatric in the same supratidal areas. These two species have very similar ecological relationships.

Preliminary observations of the shells of *Littorina pintado* and *L. picta* suggested that they were specifically distinct. However, since many species of *Littorina* show a great range of variability in the shell and furthermore, since these species are so similar ecologically, the possibility existed that *L. pintado* and *L. picta* might not be valid species. Therefore, an attempt was made to determine the morphological characteristics which might provide a broader basis for an understanding of their taxonomic relationship.

It also appeared that what have previously been termed varieties of *Littorina picta* (*L. picta* Philippi *and L. picta* var. *marmorata* Philippi) might possibly be distinct species, since each variety predominates in a different area. The relationship of these varieties was also studied.

Finally, an attempt was made to study the morphological characteristics of *Littorina scabra* which might clarify its relationship to *L. pintado* and *L. picta*. Although the habitats of the three species rarely overlap, occasionally *L. scabra* is found in proximity to *L. pintado* and *L. picta*, and smaller individuals of the three species resemble each other to some degree.

Only five specimens of *Littorina undulata* and one specimen of an undetermined species (*Littorina* sp.) were collected. The shells of these specimens are described below. The radulae and internal morphology, however, were not studied.

Because of the controversy over the generic and subgeneric names proposed for the species of *Littorina* (Winckworth, 1922), the generic name *Littorina* is retained for all the Hawaiian species. The subgeneric names are omitted in the discussion.

The entire anatomy of *Littorina pintado, L. picta* and *L. scabra* was studied, but only those morphological characteristics which were found to be diagnostic are discussed; shell, radula, male reproductive system, egg capsule and developmental type.

MATERIALS and METHODS

Collections of specimens were made at various times over a three year period from 1961 to 1963. For determinations of height and width of shell, collections of snails were made at random from several different areas, since the mean sizes were observed to vary between different substrata. The height to width ratio, however, is based only on measurements of snails collected near the Waikiki Aquarium, Oahu. Measurements of the shells were made with vernier calipers to the nearest 0.1 mm. The dimensions utilized are shown in Figure 1.

For anatomical studies, the specimens dissected and described were collected primarily from Coconut Island and near Waikiki Aquarium, Oahu. These specimens were selected because of their larger size and infrequent shell erosion. All dissections were made of living material under a binocular microscope. The results, except where otherwise indicated, are based on the dissection and exam-

[1] This paper is part of a thesis submitted to the Graduate School of the University of Hawaii in partial fulfillment of the requirements for the Ph.D. degree.

ination of at least 50 individuals of each species. Measurements of various anatomical parts, egg capsules or eggs were made either with a millimeter ruler (nearest 1.0 mm), vernier calipers (nearest 0.1 mm) or a micrometer (nearest 0.001 mm). The radulae were fixed and stained by KAY's (1957) modification of the techniques employed by ALLEN (1952) and BOWELL (1924).

Littorina pintado (WOOD)
(Plate 25, Figure 1)

Turbo pintado WOOD, 1828, Index Test. Suppl., p. 224, Suppl. pl. 6, fig. 34 (Sandwich Islands).
Littorina pintado PHILIPPI, 1847, Abbild. und Beschr. Conch., pl. 4, fig. 20 (Sandwich Islands); REEVE, 1857, Conch. Icon., X, *Littorina*, pl. 11, figs. 54 a - b. (Sandwich Islands).

DISTRIBUTION

This species is distributed from Japan through the Pacific Ocean to the Hawaiian Islands.

DESCRIPTION

Shell: There is little variation in the pattern of the shell of this species. However, eroded shells, on which the pattern is obscured, are common. The color of the shell is also fairly constant, but is lighter in some specimens because of slight surface erosion. The shells of larger and older specimens, for example, are frequently lighter in appearance than those of younger specimens. Some individuals, particularly those found in tidepools, appear darker because of algae growing on the whorls and in the sutures of the shell. The following description is based mainly on uneroded shells of younger specimens where the pattern could be seen clearly.

The shells are conoidal, of medium thickness and usually consist of seven fairly well-rounded whorls. The last two whorls in the spire are small and frequently eroded in older specimens. The surface is generally smooth, with shallow spiral lines. The shell is never ribbed strongly or beaded granularly. The axial sculpture is confined to growth striae. The pattern on the shells of larger individuals is sometimes faded. The ground color is usually pale bluish-gray on all whorls except the last one to two whorls in the spire, which are entirely reddish-brown. The five largest whorls are freckled with dark brown or black in the form of small spots which are darker toward the base of the whorls and fade toward the summit of the whorls. The aperture is oval and its outer lip thin and smooth. The external pattern can be seen within the aperture as solid, parallel, brown lines. The columella is glazed, slightly curved, dark red-brown laterally and white at its junction with the operculum.

The size range and mean size of shells vary between different areas and substrata. The ranges in size and mean sizes of shells from several different areas are summarized in Table 1. The maximum height observed in *Littorina pintado* was 22.0 mm. The apical angle in uneroded specimens is usually approximately 50 to 55°. There is sexual dimorphism in shell size, the mean size of females being significantly larger than that of males. This is shown in Table 2. The shell height to width ratio of 1.62 is the same in both sexes and fairly constant between individuals (Table 2).

Table 1

Summary of Size Distribution (mm height) on Palagonite Tuff Substratum (Koko Head and Hanauma Bay); Reef Limestone Substratum (Kahuku Point and Kaena Point); Artificial Substratum (Waikiki).

Area and Species	Sample Number	Mean Size Whole Area	Range Size Whole Area
Hanauma Bay			
Littorina pintado	624	4.92	1.9 - 8.2
Littorina picta	540	3.66	1.6 - 7.0
Koko Head			
Littorina pintado	218	4.77	1.3 - 8.5
Littorina picta	131	3.37	1.7 - 6.8
Kaena Point			
Littorina pintado	448	8.20	2.6 - 14.0
Littorina picta	29	5.14	2.6 - 8.3
Waikiki			
Littorina pintado	322	8.80	4.6 - 13.3
Littorina picta	296	7.00	3.6 - 10.3
Kahuku Point			
Littorina pintado	156	10.70	5.4 - 16.2
Littorina picta	16	6.07	3.4 - 8.3

Radula: The total length and width of the radula are given in Table 3. The radula varies considerably in length, but is less variable in width. The mean length of the radula in the specimens examined is approximately 36.0 mm and the mean width is approximately 0.190 mm. As in other species of *Littorina*, there are seven teeth in a transverse row. The radular teeth from one side of a transverse row are depicted in Figure 2 a - d. Only the bases of the rachidian and outer marginal teeth are shown, since the other teeth bases could not be seen clearly. The rachidian tooth in *L. pintado* is high-crowned, with three anterior, elongated and rounded cusps. At the base are three denticles. The central denticle is rounded, the lateral denticles are pointed. These denticles are slightly more

Table 2

Summary of Shell Measurements (in millimeters) and Analysis of Variance between Mean Height of Males and Mean Height of Females for *Littorina picta, Littorina pintado* and *Littorina scabra.* (All specimens collected at random; all are adults).

	Mean Height	Range Height	Height Interval	Mean Width	Range Width	Width Interval	Mean H/W	S^2	$S_{\bar{x}}$	t(Height only)	n
Littorina picta											
female	7.52	5.0 - 10.3	5.3	4.84	3.1 - 6.5	3.4	1.56	1.46	0.24	4.29**, d.f. 98	50
male	6.49	3.6 - 8.5	4.9	4.15	2.2 - 5.6	3.4	1.56				50
Littorina pintado											
female	9.26	5.8 - 13.3	7.5	5.73	3.7 - 8.6	4.9	1.62	2.39	0.31	3.02**, d.f. 98	50
male	8.33	4.6 - 10.7	6.1	5.15	3.0 - 6.5	3.5	1.62				50
Littorina scabra											
female	21.6	18.2 - 26.6	8.4	11.70	10.5 - 13.7	3.2	1.84	4.52	0.61	5.74**, d.f. 48	22
male	18.1	12.5 - 22.7	10.2	10.23	7.0 - 11.7	4.7	1.84				26

H/W - Height/Width Ratio
S^2 - Pooled Variance
$S_{\bar{x}}$ - Standard Error
t - Test
n - Sample number
d.f. - Degrees of freedom

Table 3

Dimensions of Radula, Radular Teeth and Number of Cusps of *Littorina pintado, Littorina picta,* and *Littorina scabra*

Species	N	RTL (mm)	ML (mm)	RTW (mm)	MW (mm)	Tooth	Microns L	Microns W	No. Cusps	Cusp Shape
Littorina pintado	20	22 - 55	36	0.18 - 0.20	0.19	Rachidian	70	60	3	Rounded
						Lateral	40	70	3	Rounded
						Inner Marginal	30	70	4	Rounded
						Outer Marginal	70	40	4	Rounded
Littorina picta	20	16 - 35	23	0.10 - 0.16	0.12	Rachidian	40	30	3	Rounded
						Lateral	40	30	3	Rounded
						Inner Marginal	30	30	4	Rounded
						Outer Marginal	40	20	4	Pointed[1]
Littorina scabra	20	25 - 39	32	0.50 - 0.55	0.54	Rachidian	100	140	3	Rounded

[1] In *Littorina picta* (ribbed variety) the cusps may be either missing or rounded, while in *L. picta* var. *marmorata* (smooth variety) the cusps are nearly always pointed and 4 in number.

N - number of specimens examined; RTL - range in total length; ML - mean length; RTW - range in total width; MW - mean width; L - length; W - width. The above measurements of radular teeth are averages only.

accentuated than those of the rachidian tooth of *L. picta* (Figure 2 e). The rachidian tooth is fairly constant in appearance between individuals and does not show as much wear as the other teeth. The lateral and marginal teeth show some variation in cusping in the anterior rows of the radula because of differential wear. The lateral tooth usually has three rounded anterior cusps and the inner marginal tooth has three to four rounded anterior cusps. The outer marginal tooth usually has four marginal cusps, also rounded.

The maximum dimension of the rachidian tooth in *Littorina pintado* is approximately 70 microns from the crown to the base. The approximate sizes of other teeth are summarized in Table 3.

Male Reproductive System: The penis of *Littorina pintado* is depicted in Figure 3 a. In mature males, the average length of the penis ranges from 4.0 to 4.5 mm and the width averages approximately 1.0 mm. There are no apparent penial glands at the base of the penis of this species, although some type of gland may be present, inconspicuously imbedded. There is no separate base, the penis joining directly to the body. The color of the penis is white, never red as in *L. picta*. The testicular duct in mature males is usually yellow-white in color.

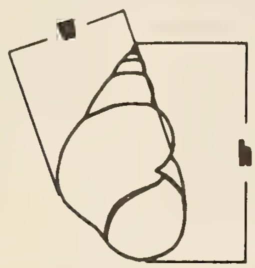

Figure 1: Dimensions of Shell measured.
h = height w = width

Egg Capsules and Developmental Type: The egg capsule of *Littorina pintado* is depicted in Plate 26, Figure 1 as it appears in polar and lateral views. The outer egg capsule averages 160 microns in diameter from a dorsal or ventral aspect. Laterally, the average maximum dimension is 100 microns. The inner egg covering averages 65 microns and the egg 60 microns in diameter. There is never more than one egg per capsule in normal capsules. Among the many thousands of egg capsules and different spawns examined, only one group of aberrant capsules containing more than one egg per capsule was observed. The reason for this aberrant spawn was not ascertained. Generally, the appearance and size of the capsules is highly uniform between different individuals. Development is oviparous with the release of egg capsules into the plankton. Breeding and spawning are continuous throughout the year.

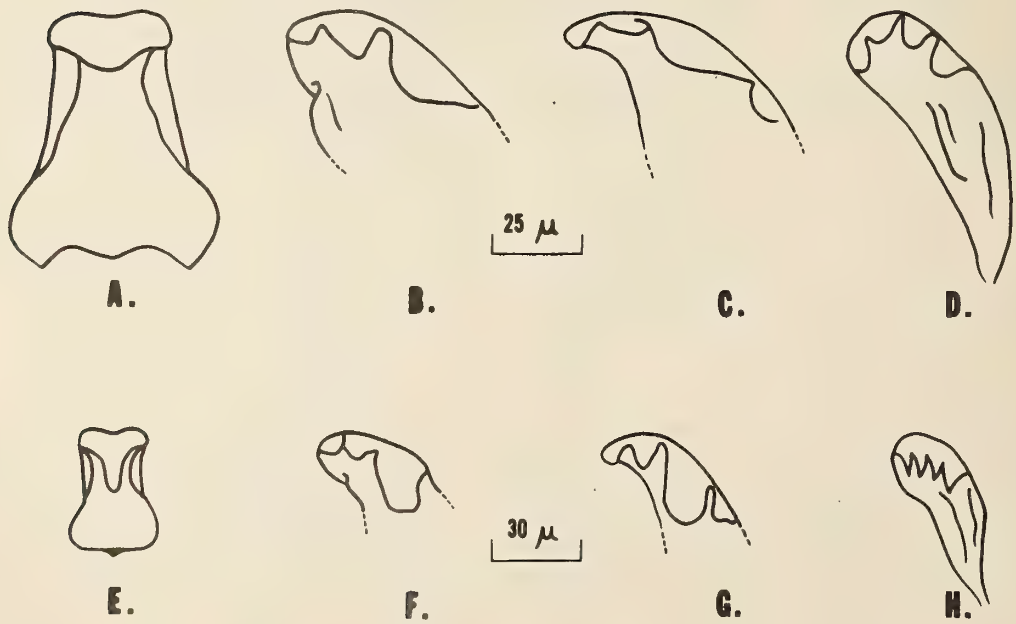

Figure 2: Radular Teeth from one Side of Transverse Row.
Anterior Edge toward Top of Page.
a to d: *Littorina pintado*. x 600.
a - rachidian tooth; b - lateral tooth; c - inner marginal tooth;
d - outer marginal tooth
e to h: *Littorina picta* (same in *L. picta* var. *marmorata*). x 525.
e - rachidian tooth; f - lateral tooth; g - inner marginal tooth;
h - outer marginal tooth.

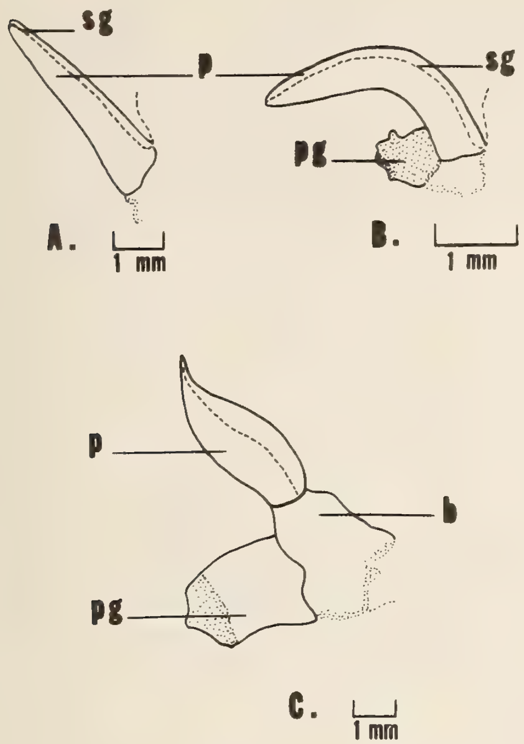

Figure 3: Penes of adult Males. Anterior View. All Penes Slightly Contracted.
A. *Littorina pintado*. x 8.
B. *Littorina picta* (Same in *L. picta* var. *marmorata*). x 10.
C. *Littorina scabra*. x 6.
b - base; p - penis; pg - penial gland; sg - sperm groove

Littorina picta Philippi
(Plate 25, Figure 2)

Littorina picta Philippi, 1845, Proc. Zool. Soc., p. 139 (Sandwich Islands).
Littorina picta var. *marmorata* Philippi, 1847, Abbild. und Beschr. Conch., pl. 3, fig. 26 (Sandwich Islands); Reeve, 1857, Conch. Icon. X, *Littorina*, pl. 15. figs. 80 a - b and fig. 81.

DISTRIBUTION

This species is distributed throughout the Hawaiian Islands. There are no definite records from any other area. *Nodolittorina picta*, from Japan, is probably not the same species (see discussion).

DESCRIPTION

Shell: The two varieties are variable in the degree of ribbing on the shell. The variety with well-marked spiral ribs is *Littorina picta* (Plate 25, Figures 2 a and b) and the smooth variety is *L. picta* var. *marmorata* (Plate 25, Figures 2 e to h). Many individuals, however, show various gradations in shell-ribbing between these two extremes (Plate 25, Figures 2 c and d). One variety usually predominates over the other depending upon the area. At Pokai Bay and Haleiwa, Oahu, for example, the ribbed variety is common and smooth forms are rare. In other areas, such as Koko Head and Hanauma Bay, the smooth forms are common and the ribbed forms rare. There are also areas, such as Waikiki and Coconut Island, Oahu, which have populations of *L. picta* including both ribbed and smooth varieties and various intergrades between the two extremes.

In the following shell description the two varieties are discussed separately and a few comments are made upon the appearance of the intergrading forms.

Littorina picta var. *marmorata:* The shells are conoidal, slightly thicker than those of *Littorina pintado* and usually consist of six fairly well-rounded whorls. The last three whorls in the spire are small and often eroded in older specimens. The surface of this variety is smooth with shallow, spiral lines and is not strongly ribbed and/or granularly beaded. The axial sculpture is confined to growth striae. The color and pattern of the shell are extremely variable except for the last one to two whorls in the spire, which are usually reddish-brown. The pattern on the other whorls varies between the following three basic types: 1) Ground color dark grey, brown or black on three largest whorls, sometimes a few small, white spots on summit of body whorl and/or summit of other whorls; 2) Ground color black, but white spots always present, usually in one to two rows around base of body whorl, one row of large white spots at summit of body whorl, sometimes a row of white spots at the summit of next two whorls; 3) Ground color white with a few irregular black patches or shell entirely white. The aperture is oval and its outer lip thin and smooth. The external pattern can be seen within the aperture. The columella is glazed, slightly curved, usually purple, but sometimes white.

Intermediate forms: These forms are similar to *Littorina picta* var. *marmorata,* except that the whorls of the spire and sometimes other whorls possess thickened ridges or ribs which follow the spiral lines. The body whorl is usually smooth or slightly ribbed with no granular beading on ribs or slight beading only.

Littorina picta: This variety is similar to *Littorina picta* var. *marmorata,* except that the spiral lines are thickened into strong ribs on all whorls. There are usually regularly spaced, granular beads present on the ribs. The variable color patterns are the same as in *L. picta* var. *marmorata,* except that the overall appearance may be darker because

the pattern is obscured by the ribs. The aperture is oval and the outer lip thin. In this variety the outer lip is serrated in line with the external spiral ridges.

The shells of both varieties are sometimes discolored from erosion and appear solid black or dark brown. Extreme erosion in the form of pitting is not common in this species as it is in *Littorina pintado,* and in general the shell seems harder and thicker.

The size range varies between areas and substrata. The ranges in size and mean sizes of populations from several different areas on Oahu are given in Table 1. As in *Littorina pintado,* the mean size of shell of *L. picta* is less on palagonite tuff substrata than on other substrata. The maximum height observed in *L. picta* was approximately 13.0 mm(ribbed variety). The apical angle in uneroded specimens is usually 50 to 55°. As in *L. pintado,* there is sexual dimorphism in shell size, the mean size of females being significantly greater than that of males (Table 2). The shell height to width ratio is 1.56, the same in both sexes and varies little between individuals (Table 2).

Radula: The radulae of the varieties of *Littorina picta* were found to be similar. Therefore, they are jointly discussed in this section. The few differences which do exist will also be discussed. The mean total length and width of the radula are given in Table 3. In *L. picta* there is also considerable variation in the length of the radula. The mean length is approximately 23.0 mm for the specimens examined. The width is less variable and is approximately 0.120 mm. The radular teeth from the right side of a transverse row are depicted in Figure 2 e - h. The rachidian in this species is high-crowned, with three anterior, elongated and rounded cusps, the largest in the center of the crown. At the base of the rachidian tooth are three small denticles. In *L. picta* the lateral denticles are rounded while the central denticle is pointed, the reverse being the case in *L. pintado.* As in *L. pintado,* the rachidian tooth is relatively constant in appearance between individuals, while the lateral and marginal teeth show some variation associated with wear of the cusps. The lateral tooth in most individuals of both varieties possesses three to four rounded anterior cusps. The inner marginal tooth in both varieties possesses three to four rounded cusps also. On the anterior edge of the outer marginal tooth of *L. picta* var. *marmorata* there are usually four pointed anterior cusps. In the ribbed variety, *L. picta,* these four cusps on the outer marginal tooth are also pointed in the posterior rows, but often absent or eroded in the anterior rows of the radula.

The radular teeth of *Littorina picta* are small, the maximum dimension of the rachidian being only 40 microns from crown to base. The sizes of other teeth are summarized in Table 3.

Male Reproductive System: The males of both varieties were dissected and their genitalia compared. No significant difference between the varieties was observed, thus the following description applies to both. The penis and accompanying glands are depicted in Figure 3 b. The average length of the penis in mature males ranges from approximately 3.0 to 3.5 mm. The width averages from 0.50 to 0.75 mm. The base of the penis joins the body directly and is not borne on a separate base. It is red in color. There are white penial glands in this species which extend to the right of the base of the penis. The testicular duct of the mature males appears to be characteristically red.

Egg Capsules and Developmental Type: The egg capsule of *Littorina picta* is shown in Plate 26, Figure 2 in lateral, dorsal and ventral views. The capsule is distinct from that of *L. pintado,* possessing several concentric ridges. The capsule and egg of *L. picta* are also larger than those of *L. pintado.* The outer egg capsule averages 180 microns in diameter from dorsal or ventral view. Laterally, the maximum dimension averages approximately 120 microns. The inner egg covering averages approximately 80 microns and the egg 75 microns in diameter. There was only one egg

Explanation of Plate 25

Figure 1: *Littorina pintado.* Adult Shells. x 2⅔

a. Dorsal View of Uneroded Shell. Waikiki, Cement and Basalt Boulder Breakwater.

b. Ventral View of Uneroded Shell. Waikiki, Cement and Basalt Boulder Breakwater.

c. Dorsal View of Eroded Shell. Koko Head, Palagonite Tuff Bench.

Figure 2: *Littorina picta* and *Littorina picta* var. *marmorata,* and intermediate forms. Adult Shells. x 3½.

a and b: *Littorina picta* (ribbed variety). Pokai Bay, Reef Limestone Bench.

c and d: Intermediate forms. Waikiki, Cement and Basalt Boulder Breakwater.

e to h: *Littorina picta* var.*marmorata* (smooth variety). Koko Head, Palagonite Tuff Bench.

Figure 3: *Littorina scabra.* Adult Shells. x 2. Coconut Island, Concrete Wall.

Figure 4: *Littorina undulata.* Adult Shells. x 2⅔.

a and b: Waikiki, Concrete and Basalt Boulder Breakwater.

c and d: Bellows Field, Reef Limestone Artificial Breakwater.

Figure 5: *Littorina* sp. Adult Shell. x 2⅔. Coconut Island. Concrete Wall.

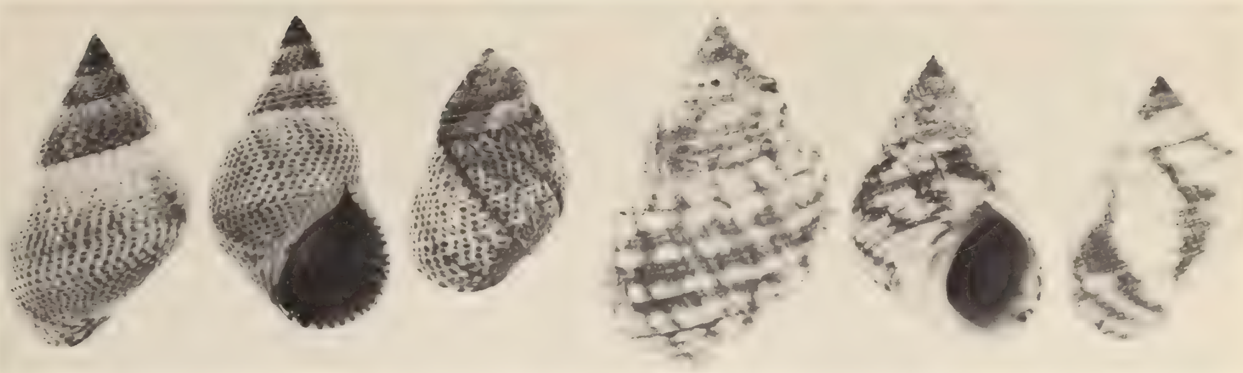

Figure 1a Figure 1b Figure 1c Figure 2a Figure 2b Figure 2c

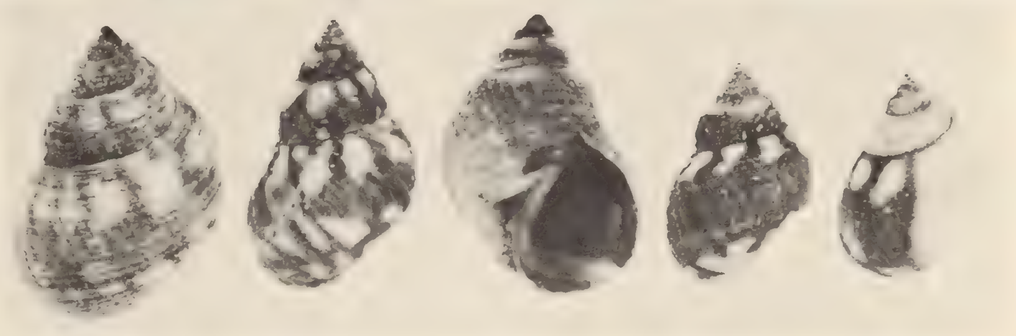

Figure 2d Figure 2e Figure 2f Figure 2g Figure 2h

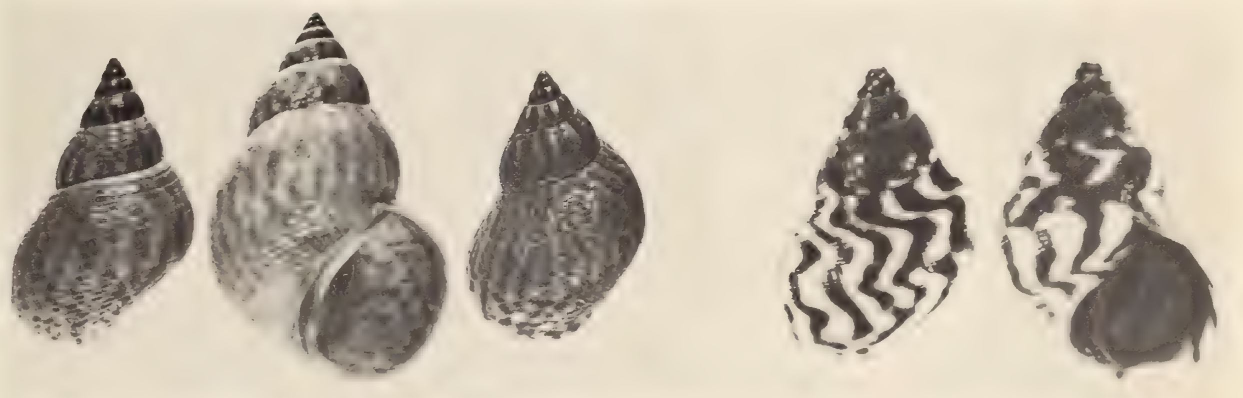

Figure 3a Figure 3b Figure 3c Figure 5a Figure 5b

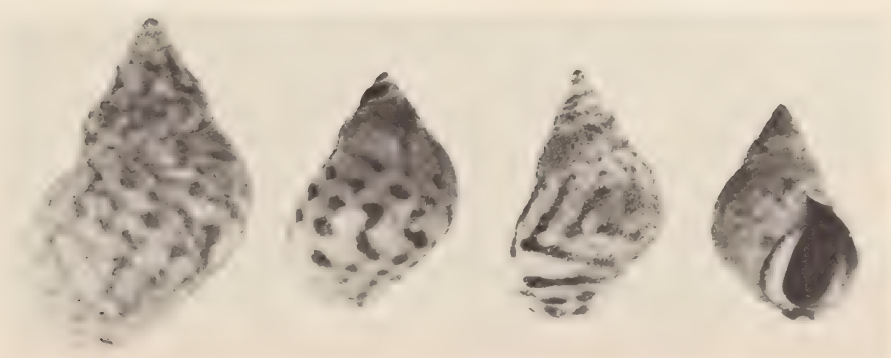

Figure 4a Figure 4b Figure 4c Figure 4d

per capsule in all the spawns examined. The appearance of the capsules is uniform between different individuals and between the two varieties. Development is oviparous as in *L. pintado*, the eggs developing in the plankton. This species, as well as *L. pintado*, breeds continuously throughout the year.

Littorina scabra (LINNAEUS)
(Plate 25, Figure 3)

Helix scabra LINNAEUS, 1758, Syst. Nat. ed. 10, p. 770.
Littorina scabra REEVE, 1857, Conch. Icon. X, *Littorina*, pl. 5, figs. 21 a - b and pl. 3, fig. 15 a, (Philippine Islands).
Littorina newcombi REEVE, 1857, Conch. Icon., X, *Littorina*, pl. 6, figs. 28 a - b, (Sandwich Islands).
Littorina ambigua (NUTTALL, MS.), REEVE, 1857, Conch. Icon. X, *Littorina*, pl. 12 fig. 64, (Sandwich Islands).

DISTRIBUTION

The distributional range of *Littorina scabra* extends from the West Coast of Africa through the Indopacific to the Hawaiian Islands and the West Coast of California; Australia and Japan.

DESCRIPTION

Shell: There is considerable color variation in this species on Oahu and some variation in pattern. However, there is little variation in shell sculpture among Oahu specimens, all examined being generally smooth. The shells are not greatly eroded.

The shells are conoidal and relatively thick. There are eight well-rounded whorls; the last two whorls in the spire are small but not usually eroded. The surface is generally smooth, but possesses well-marked spiral lines. The last spiral line at the summit of each whorl is particularly well-marked. The shells are never ribbed or granularly beaded in the Oahu specimens. The axial sculpture is confined to growth striae. The three common color varieties are: 1) Ground color light-gray or brown, sometimes with bluish tinge; marked with light or dark brown dashes which parallel the spiral lines. The variability in the pattern is due to differences in spacing of these dashes. The dashes are usually not adjacent to each other in the axial direction and the shell appears to have irregular brown zigzag lines down the whorls. The dashes are usually darker at the base of the whorls and lighter or absent at the summit of the whorls. The above description is of the most commonly observed color pattern. Less common are: 2) ground color yellow or yellow-orange, other features as in (1); and 3) ground color rose, other features as in (1), except that several bands at the summit of the whorls (delimited by spiral grooves) are solid rose with no brown dashes.

The pattern of the shell and the color are sometimes faded by surface erosion, giving the shell an overall bluish-gray color.

The aperture is oval and the outer lip thin and smooth. The external pattern can be seen within the aperture. The general color within the aperture is usually yellow and sometimes rose. The columella is glazed, slightly curved, dark-brown and/or white.

The size range in this species was determined from specimens collected from the Coconut Island population only. The size range and mean size of *Littorina scabra* at this locality are given in Table 2. The maximum height observed in Oahu specimens of *L. scabra* was 36.0 mm. The shell height to width ratio is 1.84 (Table 2). The same type of sexual dimorphism as occurred in the previous two species is also present in *L. scabra* (Table 2).

Radula: The radula of *Littorina scabra* is much wider than that of either *L. picta* or *L. pintado*, but is not as long as that of *L. pintado*, even though *L. scabra* is a much larger species. The mean length of the radula is approximately 32.0 mm and the width approximately 0.540 mm (Table 3). The dimensions of the rachidian tooth are also given in Table 3. The rachidian of *L. scabra* is quite distinct from those of *L. pintado* and *L. picta* (Figure 4).

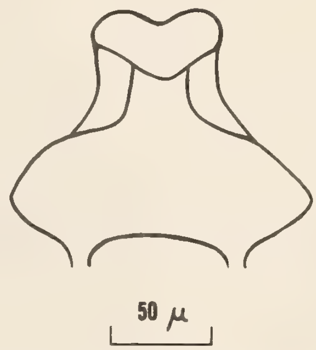

Figure 4: *Littorina scabra*. Rachidian Tooth. x 360. Anterior Edge toward Top of Page.

It is low-crowned, the base is quite flaring and the tooth is much larger. As in *L. pintado* and *L. picta* there are three anterior rounded cusps, the largest occurring in the center of the crown, but the location of the three denticles at the base is quite different. The maximum dimension of the rachidian is across the base and measures 140 microns (Table 3).

Male Reproductive System: The penis of *Littorina scabra* is depicted in Figure 3 c and is significantly different from that of *L. pintado* and *L. picta* in that it is borne on a separate base instead of joining into the body directly. The

length of the penis in mature males ranges from 4.5 to 5.0 mm and the width is approximately 2.0 mm. The color of the penis is yellow-white. The penial gland is white and well-developed in this species.

Eggs and Mode of Development: *Littorina scabra* is ovoviviparous and does not release planktonic egg capsules as do *L. pintado* and *L. picta,* but develops eggs within the mantle cavity to a late veliger stage, at which time they are shed into the water. There is no external capsule as in *L. pintado* and *L. picta.* A simple egg covering, however, is present and measures approximately 80 microns in diameter. The egg is approximately 75 microns in diameter. This species also breeds continuously throughout the year.

Littorina undulata Gray
(Plate 25, Figure 4)

Littorina undulata Gray, 1839, Zool. Beechey's Voy., p. 140, no figures; Reeve, Conch. Icon. X, *Littorina,* pl. 13, figs. a, b, c, d, (Society and Philippine Islands).

DISTRIBUTION

The distribution of this species is from Japan and Australia through the Pacific to the Society and Philippine Islands and also Johnston Islands. It has not been previously noted from the Hawaiian Islands, except by Tinker (1958).

DESCRIPTION

Shell: Only four specimens of *Littorina undulata* were found on Oahu during this study. Two of the specimens were collected from an artificial sea wall near Waikiki Aquarium, and two from an artificial sea wall at Bellows Field Air Force Base. None of the specimens are very large (compared to those in the Bishop Museum collections), the largest being approximately 16.5 mm in height and 9.6 mm in width. All four have green algae on the surface of the shell and all four are slightly eroded, obscuring the pattern to some degree. The basic pattern, however, can be seen partially.

The shell is conoidal and of medium thickness. There are from 6 to 7 fairly well-rounded whorls. This could not be determined exactly because the spires of all four specimens were eroded. The surface is smooth with a few shallow, spiral lines. None of the specimens are ribbed or granularly beaded. The axial sculpture is confined to growth striae and the sutures are well-constricted. The ground color is light gray or tan on the three largest whorls. The whorls are marked with irregular, light red-brown zigzag lines. The aperture is oval and the outer lip thin and smooth. The external pattern can be seen within the aperture in the form of brown spots on a yellow background. The columella is glazed, slightly curved, purple laterally and white at its junction with the operculum.

The sizes of the specimens are 16.5 x 9.6 mm, 12.4 x 7.5 mm, 11.8 x 7.2 mm, and 11.2 x 6.8 mm. The mean shell height to width ratio based on the four specimens is 1.69.

Littorina sp.
(Plate 25, Figure 5)

One female specimen of an undetermined species was found at Coconut Island in February 1963. It was located on the southeastern concrete sea wall near the entrance of the lagoon and found next to several specimens of *Littorina pintado* and *L. picta.* Its appearance was sufficiently different from that of the other species so that it was immediately noticed. Attempts to identify this species were unsuccessful since no description from the literature seemed to fit this particular specimen. The closest resemblance is to the shell of *Littorina zebra* (Wood) (Reeve, 1857). An examination of the collections of the Bishop Museum did not reveal any shells collected from the Hawaiian Islands which resembled this specimen.

DESCRIPTION

Shell: The specimen is not eroded and thus the pattern and number of whorls can be seen clearly.

The shell is conoidal and relatively thick. There are seven well-rounded whorls. There is no deciduous periostracum and the surface is smooth. The spiral lines are not well indented. The axial sculpture is confined to growth striae. The ground color is white. The body whorl of the shell is marked with irregular zigzag lines in the axial direction. These lines are relatively broad and dark chocolate brown in color. The next four whorls of the spire are solid chocolate brown in color and the last two whorls of the spire are light reddish-brown. The aperture is oval and the outer lip thin and smooth. The color and pattern within the aperture are similar to the external pattern of the body whorl. The columella is glazed, slightly curved, and purple in color.

Explanation of Plate 26

Figure 1: *Littorina pintado.* Egg Capsules Immediately after Spawning. Eggs in One-Cell Stage. At Far Left is a Capsule in Lateral View, the Others are in Polar View. x 175.

Figure 2: *Littorina picta* (Same in *Littorina picta* var. *marmorata*). Egg Capsules Immediately after Spawning. Eggs in One-Cell Stage. At Left Center is a Capsule in Lateral View, the Others are in Polar View. x 175.

Figure 1

Figure 2

The shell is 14.7 mm in height and 9.0 mm in width. The apical angle is approximately 50°. The shell height to width ratio is 1.64.

Body: The most notable characteristic of this specimen is the color of the foot, head and body. All are bright yellow. The radula, reproductive organs and spawning were not studied.

CONCLUSIONS AND DISCUSSION

The characteristics which differentiate *Littorina pintado, L. picta, L. scabra, L. undulata* and *Littorina* sp. are summarized in Tables 4 and 5. On the basis of the shell, radula, penis and penial glands, testicular duct, developmental type and egg capsule it appears that *L. pintado* and *L. picta* are distinct species, although sympatric and with similar ecological relationships.

In addition, on the basis of the similarities of the radulae, male reproductive system, egg capsules and development, the two varieties of *Littorina picta* appear to be the same species and not separate species, despite the variation in shell ribbing and substratum occupied. Although the extreme forms of each variety superficially appear to be different species, the existence of many individuals with shells showing intergradations in ribbing between the two extremes gives a strong indication that they are the same species. Certain observable differences in the cusps of the radular teeth could be due to differential wear from feeding on different surfaces.

Littorina scabra is easily distinguished from *L. pintado* and *L. picta* on the basis of the characteristics studied, particularly in the male genitalia and mode of reproduction.

I have found no reference to previous work on the internal morphology of *Littorina pintado, L. picta* and *L. scabra,* or to the use of internal morphological characteristics in the identification of these species. Most previous identifications of species of *Littorina* were based mainly on shell characters, or in a few cases on egg capsules. LEIDY (1845) described the anatomy of *Littorina angulifera* LAMARCK. *Littorina angulifera* is thought to be a subspecies of *L. scabra* by J. ROSEWATER (1963) of the U. S. National Museum and BEQUAERT (1943). The radulae and penis of *L. angulifera* depicted by LEIDY in Figures 1 and 2 of his work closely resemble those of *L. scabra* studied here. However, LEIDY does not show the presence of a ctenidium in *L. angulifera* nor mention it in his description. A ctenidium was always observed to be present in individuals of *L. scabra* which were dissected in this study.

Although it is well recognized that the shells of many species of *Littorina* are extremely variable in appearance, no conclusive studies have been made that were able to determine the source of this variation. COLMAN (1932) pointed out that sufficient numbers of individuals of a species, collected over a wide area, must be examined to determine the presence or absence of intergrades before identifying any variation as a separate species. It was observed here that *L. scabra* is variable in shell coloration and *L. picta* is variable in ribbing on the shell. I have not sufficiently studied *L. scabra* to determine the possible sources of the color variation in this species. In *L. picta,* however, the predominance of certain varieties over others on certain substrata indicates that the variation in shell ribbing may be due, at least in part, to environmental differences, perhaps related to wave action, the chemical composition of the substratum itself or to the food available on the substratum.

The variation of the radula within a single species has been observed by PEILE (1937) and ALLEN (1952) in *Littorina*. PEILE believes that such differences as the obliteration or absence of cusps may arise from their wear by the surface on which the snail feeds. He observed that the most anterior rows of teeth were worn to the greatest degree and that within the rows the marginal teeth were particularly worn while the inner teeth showed the least wear. The same observations were made of the radulae of the species considered here. The radula of the ribbed variety, *L. picta,* appears to be more worn than that of the smooth variety, *L. picta* var. *marmorata.* The cusps of the outer marginal tooth are frequently absent in *L. picta.* It seems possible that these differences in the teeth may be correlated with the observation that *L. picta* is usually found in areas with a hard limestone substratum. *Littorina picta* var. *marmorata,* on the other hand is predominant in areas with a softer palagonite tuff substratum.

HABE (1956 a) described the radular teeth of the genus *Nodolittorina* in the Indo-Pacific region. There is some resemblance between the radular teeth which he depicted in his figures and the radular teeth of *L. picta* described here, particularly between the rachidian teeth. However, there are small differences between the shapes of the teeth.

In another study, HABE (1956 b) included a photograph of the egg and capsule of what he identified as *Nodolittorina picta* (PHILIPPI). These capsules differ from those of *Littorina picta* in Hawaii in that their lower circumference is greatly serrated. Such serration of the capsule has never been observed in any egg capsules of *L. picta* in the Hawaiian Islands. Further, the illustration of a *Nodolittorina picta* shell in KURODA & HABE (1950) shows considerable differences from the shell of *L. picta* from Hawaii. Because of these discrepancies in the appearance of the capsules of HABE's *Nodolittorina picta* and those of *L. picta* from Hawaii and the further dissimilar-

Table 4

Summary of Characteristics Distinguishing *Littorina picta, Littorina pintado* and *Littorina scabra*

	Littorina picta	*Littorina pintado*	*Littorina scabra*
Shell:			
No. of Whorls	6	7	8
Ribbing	In some varieties	Never	Not on Oahu
Pattern	Variable-mottled	Flecked or checkered	Variable-zigzag lines
Maximum Height	13.0 mm	22.0 mm	36.0 mm
H/W Ratio	1.56	1.62	1.84
Color of Columella	Purple	Dark red-brown	Dark red-brown
Radula:			
Teeth (Max. dim.)			
Rachidian			
Height	40 microns	70 microns	100 microns
Width	30 microns	60 microns	140 microns
Ant. cusps	3	3	3
Post. denticles	3-Center pointed Lateral rounded	3-Center rounded Lateral pointed	
Lateral			
Cusps (No.)	3-4	3	- - - - -
Inner Marginal			
Cusps (No.)	3-4	3-4	- - - - -
Outer Marginal			
Cusps (No.)	4	4	- - - - -
Shape of cusps	Pointed (sometimes absent)	Rounded	- - - - -
Color of Body:	Yellow-white with black pigment spots	Same	Same
Penis:			
Color	Red	White	Yellow-white
Separate base	No	No	Yes
Penial glands	Yes	No	Yes
Testicular duct:	Red	Yellow-white	Yellow-white
Developmental type:	Oviparous	Oviparous	Ovoviviparous
Egg capsule:			
Shape	"Barrel" (See Plate 26, fig. 2)	"Helmet" (See Plate 26, fig. 1)	None
Diameter	180 microns	160 microns	
Egg:			
Diameter	80 microns	60 microns	75 microns

All of the above figures represent mean values only.

Table 5

Summary of External Characteristics of *Littorina undulata* and *Littorina* sp.

	Littorina undulata	*Littorina sp.*
Shell:		
No. of Whorls	6-7	7
Ribbing	No	No
Height (Maximum)	16.5 mm (4 specimens)	14.7 mm (1 specimen)
H/W Ratio	1.69	1.64
Pattern	Light red-brown zig zag lines - variable.	Dark chocolate-brown zig zag lines.
Color of Columella	Purple	Purple
Color of Body:	Yellow-white with black pigment spots.	Bright yellow, no black pigment spots.

ities in the appearance of their respective shells, it seems probable that *L. picta* from the Hawaiian Islands is specifically distinct from HABE's so-called *Nodolittorina picta.*

TRYON (1887) on the basis of shell characteristics, suggested that *Littorina picta* was synonymous with *L. planaxis* from the West Coast of the United States. However, specimens of *L. planaxis* which I have examined (collected near Hopkins Marine Station, California) possessed differences in the shape and location of the penial glands. The shells also have a different appearance and while the shell of *L. planaxis* has 3 whorls (JOHNSON & SNOOK, 1935), that of *L. picta* has six whorls.

No descriptions of the egg capsules or development of *Littorina pintado* or *L. picta* have been made previously, except for the description of the egg capsules of *L. pintado* by OSTERGAARD (1950). His description and figures, however, lack certain pertinent details and do not exactly resemble the capsules described here. OSTERGAARD's measurements are also different from those reported here. The irregularly-shaped capsules drawn by OSTERGAARD, 1950 (fig. 20), and the presence of two eggs in one of these capsules are probably of rare occurrence and may be a result of an aberrant spawn.

As previously mentioned, *Littorina scabra* is thought to be synonymous with *L. angulifera. Littorina angulifera* has been studied by LEBOUR (1945) in Bermuda. In general, the reproduction in *L. angulifera* which she describes is similar to that observed in *L. scabra* from Hawaii. *Littorina scabra,* in Hawaii, however, has a year-long breeding season, while *L. angulifera* is thought to be seasonal in breeding (LEBOUR, *l. c.*).

ACKNOWLEDGMENT

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LITERATURE CITED

ALLEN, J. F.
1952. The morphology of the radula of *Littorina irrorata* (SAY). Trans. Amer. Microsc. Soc. **71** (2): 139 - 145.

BEQUAERT, JOSEPH CHARLES
1943. The genus *Littorina* in the western Atlantic. Johnsonia **1** (7): 1 - 27; 7 plts.

BOWELL, E. W.
1924. The mounting of radulae for photomicrography. J. R. Microscop. Soc.: pp. 292 - 294.

COLMAN, JOHN
1932. A statistical test of the species concept in *Littorina.* Biol. Bull. **62**: 223 - 243.

HABE, TADASHIGE
1956 a. Notes on the systematic position of three American sea shells. Venus **19**: 95 - 100.

1956 b. The floating egg capsules of the Japanese periwinkles (Littorinidae). Venus **19**: 117 - 121.

JOHNSON, MYRTLE E., & H. J. SNOOK
1927. Seashore animals of the Pacific Coast. The Macmillan Co., New York.

KAY, E. ALISON
1957. Systematics of the Cypraeidae. Ph. D. Thesis; University of Hawaii.

KURODA, TOKUBEI & TADASHIGE HABE
1950. Illustrated catalogue of Japanese shells.

LEBOUR, MARIE V.
1945. The eggs and larvae of some prosobranchs from Bermuda. Proc. Zool. Soc. London **114**: 462 - 489.

LEIDY, J.
1845. Anatomical description of the animal of *Littorina angulifera* Lam. Boston Journ. Nat. Hist. **5**: 344 - 347.

OSTERGAARD, JENS MATHIAS
1950. Spawning and development of some Hawaiian marine gastropods. Pac. Sci. **4** (2): 75 - 115.

PEILE, A. J.
1937. Some radula problems. Journ. Conch. **20**: 292 - 304.

REEVE, LOVELL AUGUSTUS
1857. Conchologia Iconica: or, illustrations of the shells of molluscous animals. London, Vol. X: *Littorina.*

Rosewater, Joseph
1963. Problems of species analogues in world Littorinidae. Ann. Repts. Amer. Malac. Union, Bull. 30: 5 - 6.

Tinker, Spencer Wilkie
1958. Pacific sea shells; a handbook of common marine mollusks of Hawaii and the South Seas. 2nd. rev. ed.; 239 pp.; illust. C. E. Tuttle Co. Vermont.

Tryon, George Washington, Jr.
1887. Manual of conchology, structural and systematic. IX. Solariidae, Ianthinidae, Trichotropidae, Scalariidae, Cerithiidae, Rissoidae, Littorinidae. 9: 1 - 488; 71 plts. Philadelphia.

Winckworth, Ronald
1922. Nomenclature of British Littorinidae. Proc. Malac. Soc. London 15: 95 - 97.

On the Distribution of *Tresus nuttalli* and *Tresus capax*

(Pelecypoda: Mactridae)

in the Waters of Puget Sound and the San Juan Archipelago

BY

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(Plate 27; 1 Text figure)

INTRODUCTION

Tresus capax (Gould, 1850) (= *Schizothaerus capax*) and *Tresus nuttalli* (Conrad, 1837) (= *Schizothaerus nuttalli*) are both widely distributed on sheltered intertidal flats along the West Coast of North America. They are frequently sympatric in their distribution, although in Puget Sound and adjoining coastal areas *T. capax* appears to be the dominant form. Though both species are frequently used as food and game in the coastal states of California, Oregon, and Washington there is a paucity of literature concerning them.

During the period from June 1960 to June 1962 the author had the opportunity to investigate the symbiotic relationships between the pinnotherid crabs, *Pinnixa faba* (Dana, 1851) and *P. littoralis* Holmes, 1894, and their definitive host, the horse clam, *Tresus capax*. At the same time many observations were made on the distribution and biology of the host bivalve as well as the related *T. nuttalli*. This information is reported in the present paper.

The author gratefully acknowledges the advice and assistance of his graduate faculty in the Department of Zoology, University of Washington. Special thanks are due to Dr. Robert Fernald, Director, the Friday Harbor Laboratories, who made available the facilities of the laboratories. The author is indebted to Prof. Fred Telonicher, Humboldt State College, Arcata, California, for bringing to his attention as an undergraduate student the interesting pinnotherid - host associations. The study was made during the tenure of a predoctoral grant (No. 10,872) from the National Institutes of Health, U. S. Department of Public Health.

COLLECTING SITES AND METHODS

Two primary collecting sites were visited. One of these, Quartermaster Harbor, is a long, narrow embayment in southern Vashon Island, Washington (47° 22′ 30″ N; 122° 27′ 00″ W). The water of Quartermaster Harbor is received principally from southern Puget Sound. The second site was Garrison Bay at the western end of San Juan Island, Washington (48° 35′00″ N; 123° 09′05″ W). This island is part of the San Juan Archipelago and

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its shores are surrounded by waters derived from the Straits of Juan de Fuca and the Georgia Straits.

A grid system was established between the extreme high tide level and -2.2 ft tide level at both sites. Clams were removed in a systematic manner from 25 m^2 quadrats formed by the grid. All levels of the intertidal zone were thus uniformly sampled. Both sites were usually visited monthly and 10 to 25 bivalves were dug at each visit. The number collected on each date was determined by prevailing tidal and weather conditions. The species, length, dorso-ventral shell depth, and percent infestation by the pinnixids were determined for each *Tresus*. In addition the depth of substrate from which they were collected, was noted, and the air, surface, and burrow temperatures were recorded. Depths were noted as the distance from the surface of the substrate to the uppermost margin of the shell. Surface temperatures were read with the bulb of the thermometer shaded and resting directly on the surface of the substrate.

OBSERVATIONS

Differences were noted in the distribution of the two species at the two primary collecting sites. Whereas both *Tresus capax* and *T. nuttalli* were found at the Quartermaster Harbor site, although in different relative abundance, *T. nuttalli* was not found at Garrison Bay. This was true throughout a year of collecting (4 May 1961 to 18 June 1962). Of 204 *Tresus* dug at Quartermaster Harbor, 194 were *T. capax* and 10 were *T. nuttalli*. All 252 *Tresus* collected at Garrison Bay were *T. capax* (see Table 1).

Whereas the distribution of the two species was sympatric at one site, *Tresus nuttalli* appeared to be excluded from the second area. As *T. nuttalli* has been reported from other intertidal flats in the San Juan Archipelago (Swan & Finucane, 1952) it is probable that there were local foci of reproducing adults from which veliger larvae might spread. The author collected *T. nuttalli* in June 1961 from False Bay, San Juan Island, a relatively short distance from the Garrison Bay study area.

The differences in the distribution of the two clams may be due to more specific characteristics of the two environments. The site at Quartermaster Harbor was located on a gently sloping (9°) beach. During the lowest low water of a - 2.2 ft tide, approximately 63 m of beach was exposed between the low tide line and the extreme

Table 1

Occurrence of *Tresus capax* and *Tresus nuttalli* in collections made at Quartermaster Harbor and Garrison Bay, Washington; 4 May 1961 to 18 June 1962.

Quartermaster Harbor				Garrison Bay			
date	total *Tresus*	*Tresus capax*	*Tresus nuttalli*	date	total *Tresus*	*Tresus capax*	*Tresus nuttalli*
4 V 1961	13	13	0				
1 VI	9	9	0	14 VI 1961	24	24	0
12 VI	16	16	0	26 VI	13	13	0
28 VI	16	12	4	30 VI	7	7	0
26 VII	11	11	0	11 VII	18	18	0
				29 VII	15	15	0
				8 VIII	22	22	0
				22 VIII	32	32	0
22 IX	13	13	0	20 IX	22	22	0
24 X	14	13	1	25 X	10	10	0
21 XI	10	10	0	22 XI	20	20	0
20 XII	11	9	2	21 XII	21	21	0
17 I 1962	12	12	0				
3 II	18	18	0	2 II 1962	14	14	0
2 III	12	12	0	3 III	14	14	0
7 IV	14	13	1	8 IV	20	20	0
5 V	13	13	0				
26 V	8	6	2				
18 VI	14	14	0				
Totals:	204	194	10		252	252	0

Table 2

Variations in the "on site" substrate surface and siphon tube temperatures at Quartermaster Harbor; 150 feet below extreme high tide level.

date	substrate surface (shaded); °C	siphon tube, 6 cm below surface; °C
12 VI 1961	23.0	17.5
13 VII	26.5	20.0
26 VIII	24.0	18.0
3 II 1962	8.0	8.0
2 III	5.0	5.0

high tide level. The surface of the substrate consisted of a 7 to 10 cm layer of clean, fine sand. Below this the sediment was composed of a highly reducing glacial till containing large quantities of broken shell and organic debris. This layer was up to 75 cm thick. There was a distinct interface between these two strata. Whereas the sandy surface was relatively compact, the deeper materials were loose, porous, and easily dug.

The Garrison Bay site was quite different, however. The angle of slope was greater, 14.5°, and only 39 m of beach was exposed during a low tide of - 2.2 ft. The surface sediment consisted of a silty mud ranging from 5 to 8 cm thick and overlaid a hard, compact clay. The latter was quite dry and when a clam was removed from its burrow in the clay there was very little moisture on either the surrounding substrate or the valves of the clam.

Tresus were found at different depths within the sediment at the two sites. At Quartermaster Harbor individuals were taken between 9 and 45 cm below the surface, with a mean depth of 23.5 cm. At Garrison Bay, however, *Tresus* occurred from the surface to 27 cm with a mean of 14 cm.

The clams at Quartermaster Harbor were thus apparently able to burrow to a considerably greater depth than those found at Garrison Bay. The underlying hardpan found at the latter site was probably an impediment to deeper movement.

If, as was suggested by Swan & Finucane (1952), *Tresus nuttalli* is subject to killing freezes then its distribution might be predicted. Those juveniles developing in a substrate which permits relatively deep burrowing would survive, whereas individuals growing at or near the surface would perish as a consequence of intolerable changes in surface temperature. That an overlying substrate does provide effective insulation against higher temperatures in an intertidal environment can be judged from Table 2. On two occasions during the winter of 1961-1962 it was observed that the upper one or two centimeters of substrate at the Garrison Bay site were freezing whereas the lower strata were loose and unfrozen.

Tresus nuttalli collected at Quartermaster Harbor were found at or below the 150 ft line from extreme high tide level; *T. capax* were distributed up to the 60 ft level. The length of time that the *T. nuttalli* were uncovered during any one tidal period was thus less than that for *T. capax* found higher in the intertidal zone. The former species would appear to avoid undue or prolonged exposure to widely varying seasonal temperatures.

Kanwisher (1955), in a study on freezing in intertidal animals, states that: "No animal was found to stand low temperatures and large internal ice formation that is not faced with these conditions in nature." As *Tresus nuttalli* in Puget Sound is at or near the northern limit of its range it is quite probable that temperature correlated with sediment-depth is a controlling factor in its distribution in that area.

The size attained by *Tresus capax* at the Garrison Bay site was greater than at Quartermaster Harbor (Figure 1). While at Quartermaster Harbor the clams did not exceed 160 mm in length, at Garrison Bay 27 percent of the total specimens collected fell within the 161 - 200 mm length group. Swan (1952) presents experimental evidence that substrate texture and composition may affect the linear growth rate, shell weight, and linear dimensions of the bivalve *Mya arenaria*. More recently Addicott (1963) reported that a fossil *Tresus nuttalli* found in a restricted position in a Pleistocene sandstone had grown abnormally. It would appear that sediment conditions can affect linear shell growth and maximum size and the differences in growth of *T. capax* can probably be attributed to the sediment composition at the two sites.

The position of the two clams in the two substrate types is also of interest. Whereas both *Tresus capax* and *T. nuttalli* at Quartermaster Harbor were oriented with their antero-posterior axis at an angle approximately 45° to the vertical, as depicted for *T. nuttalli* by Pohlo (1964: 322), at Garrison Bay *T. capax* were frequently found with this

Explanation of Plate 27

Figure 1: Visceral mass of *Tresus capax*. Left mantle tissue reflected to reveal visceral skirt which overlies tip of ruler. Compare with Figure 2.

Figure 2: Visceral mass of *Tresus nuttalli*. Note the lack of a visceral skirt.

Figure 1

Figure 2

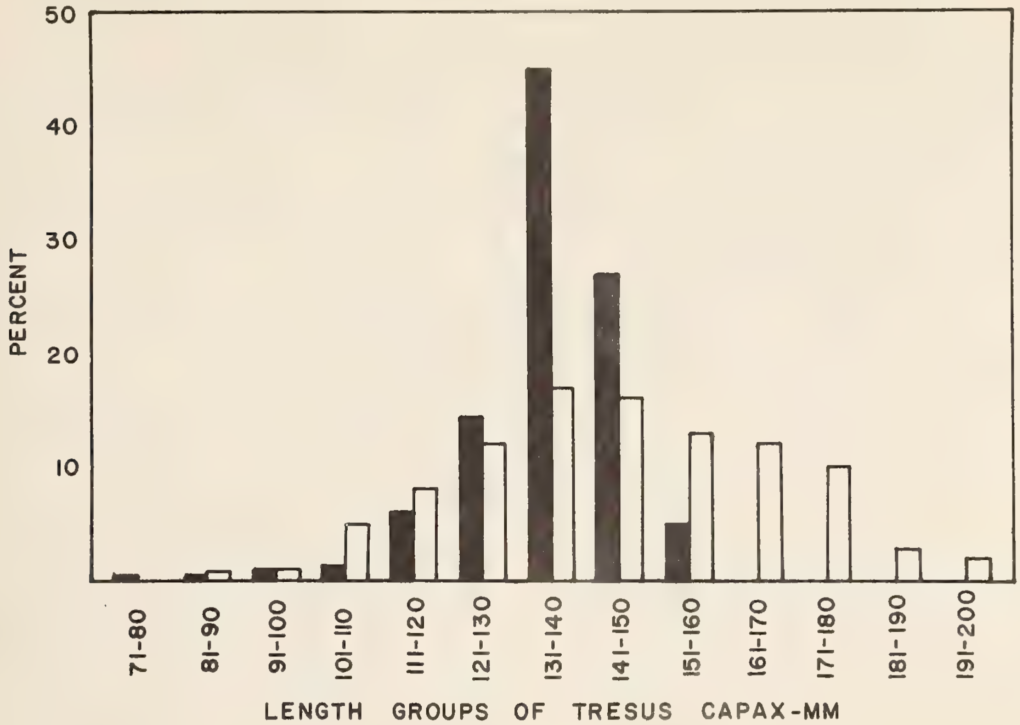


Figure 1: Percent of total *Tresus capax* collected at Quartermaster Harbor (solid bars) and Garrison Bay (open bars) found in each length group.

axis parallel to the horizontal. In the latter case the siphons frequently left the valves at almost a 90° angle to the antero-posterior axis of the clam. These differences are probably adaptations to living in an environment which restricts the depth to which the bivalve is able to burrow.

In addition to their distribution the two bivalves showed other obvious biological differences. These are of particular interest as Swan & Finucane (1952) posed the following questions: "1. Are *S. n. nuttallii* and *S. n. capax* one or two species? 2. How can they be distinguished? 3. Do they have differences in habits and/or habitat preference?" The last question would appear to be answered by the data given above.

With regard to the first and second questions posed, *Tresus capax* has an anatomical feature not possessed by *T. nuttalli*. This is the visceral skirt described by Kellogg (1915). It is a prolongation of the inner palp lamellae and forms a curtain-like structure which hangs from the dorsal extremities of the visceral mass covering much of the posterior regions of the latter (see Plate 27, figures 1 and 2). The adult female of both species of pinnotherid crab is almost invariably found under this "skirt" and appears to feed exclusively on foodstrings formed by the ciliary tracts of the structure. Along with the differences which Swan & Finucane (1952) report in the shape of the valves and the nature of the siphonal plates, the visceral skirt serves to readily distinguish what are obviously two species. Finally it is significant that the pinnixid crabs infest only *T. capax*. No *T. nuttalli* have been found infested with either of these symbionts even though adult *T. capax* are almost one hundred percent infested with adult crabs. The two clam species are similar in size as adults; wax casts of the mantle cavities of similar sized individuals of both species displace almost equal amounts of water. It is therefore assumed that *T. nuttalli* is sufficiently large to accommodate the adult crabs. Telonicher (personal communication) reports that in Humboldt Bay, California, the pinnotherids are also restricted to *T. capax*. However, he has found them with *T. nuttalli* at Bodega Bay, California. Is it possible that they infest *T. nuttalli* in more southerly environments where *T. capax* does not occur or the populations are greatly reduced? This matter deserves further attention.

CONCLUSIONS

Observations on the distribution of *Tresus capax* and *T. nuttalli* reported in this paper would seem to substantiate the suggestion of SWAN & FINUCANE (1952) that *T. nuttalli,* at the northern periphery of its range, is subject to death caused by freezing. The clam survives only where it can burrow sufficiently deep to avoid the temporary surface freezes which periodically occur in the Puget Sound area. At Quartermaster Harbor the substrate is such that both *T. capax* and *T. nuttalli* can burrow below the freeze zone and the adults of both species persist in the littoral region. At Garrison Bay an underlying hardpan does not permit the clams to dig sufficiently deep and only *T. capax* persists there as adults.

At the Garrison Bay site, where it occurs in the interface between a clay hardpan and an overlying silty mud, *Tresus capax* grows to a larger size than it does at Quartermaster Harbor.

In addition to distinctive characteristics in its shell and siphonal plates, *Tresus capax* has a visceral skirt which is lacking in *T. nuttalli.* The pinnixid crabs, *Pinnixa faba* and *P. littoralis,* coexist only with *T. capax* in the environments studied.

LITERATURE CITED

ADDICOTT, WARREN O.

1963. An unusual occurrence of *Tresus nuttalli* (CONRAD). (Mollusca: Pelecypoda) The Veliger **5** (4): 143 - 145; 3 Text figs. (1 April 1963)

KANWISHER, J.

1955. Freezing in intertidal animals. Biol. Bull. **109** (1): 56 - 63

KELLOGG, J.

1915. Ciliary mechanisms of lamellibranchs. Journ. Morph. 26: 625 - 701

POHLO, ROSS H.

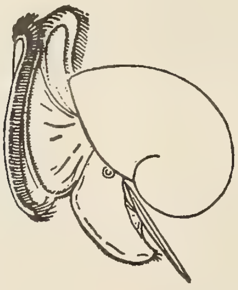
1964. Ontogenetic changes of form and mode of life in *Tresus nuttalli* (Bivalvia: Mactridae). Malacologia **1** (3): 321 - 330 6 text figs.

SWAN, EMERY FREDERICK

1952. The growth of the clam *Mya arenaria* as affected by the substratum. Ecology **33** (4): 530 - 534

SWAN, EMERY FREDERICK & JOHN H. FINUCANE

1952. Observations on the genus *Schizothaerus.* Nautilus **66** (1): 19 - 26; plts. 2 - 4



The Geographical Distribution of Cowries

(Mollusca: Gastropoda)

BY

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(2 Text figures)

The first attempt to outline the whole geographical distribution of the living species of cowries (Cypraeidae) has been made by Hidalgo (1906/07, p. 182-241); unfortunately Hidalgo was rather uncritical so that about 15 per cent of his indications of habitat are erroneous (Schilder 1952, p. 48). These zoogeographical studies have been continued by this writer in several papers (1924, 1927, 1932, 1940), especially in the "Prodrome" (1938/39) and in the catalogue of living and fossil Cypraeacea (1941), as well as by Steadman & Cotton (1946). Further studies made during the last twenty years show that many corrections are necessary, as many species proved to be more widely distributed than thought previously (e.g. Schilder 1964), whereas for other species the area of distribution should be restricted, because some indications seem not to be reliable (e.g. Schilder 1960).

Our present knowledge of the distribution of living cowries is still far from complete; nevertheless it seems to be advisable to publish a revised critical list. But one should consider that collecting beach specimens at any locality does not prove the species to live there (Spicer 1941, Ingram & Kenyon 1945): thus, for instance, I do not believe that the many Central Pacific cowries recently collected as beach shells at Clipperton Island (Hertlein & Allison 1960) really belong to the West American fauna. And even collecting single living specimens does not exclude their being introduced recently by man (Schilder 1960).

In my papers mentioned above I have used various systems of describing the distribution of cowries both as accurately and as briefly as possible, and Steadman & Cotton (1946) adopted a similar system of abbreviations. In the present paper I shall try to introduce a system of classification of faunas not restricted to the warm seas inhabited by the cowries (Cypraeidae) and their allies (Ovulidae, Eratoidae) as before, but embracing all shores of the globe so that my proposed system may be used also by students of other littoral mollusca living in cold zones.

This universal system looks rather complicated, but it allows any degree of exact description of the distribution to be expressed in the shortest way, without using the names of localities which often can be found only with great difficulty in an atlas. It has been established on the following seven principles:

1—The classification of the zoogeographical zones and provinces ("faunas") follows the arrangement established by Ekman (1935, p. 338, fig. 165; see also Schilder 1956(p. 85, fig. 36).

2—The denomination of these 9 provinces has been expressed by the digits 1 to 9 according to the chief points of the compass (Schilder 1956, p. 69): they begin with the centre and the north and proceed clock-wise so that the even figures designate the four chief quadrants of the compass, and the odd figures designate the intermediate directions. Therefore the nine digits express:

9 = N.W.	2 = N.	3 = N.E.
8 = W.	1 = central	4 = E.
7 = S.W.	6 = S.	5 = S.E.

According to this system, the five zones and the nine provinces of the littoral fauna (Ekman 1935) may be arranged as follows:

Zones:	Provinces:		
Arctic	2 = Arctic		
Northern temperate (or boreal)	9 = North Atlantic		3 = North Pacific
Tropical	8 = Western	1 = Indian	4 = Pacific
Southern temperate (or antiboreal)	7 = South American		5 = South Australian
Antarctic	6 = Antarctic		

The Western province (8) called hesperotropical by SCHILDER (1956, p. 74) contains three well separable subprovinces: the West-American, the East-American, and the West-African, while the Indian and the Pacific provinces (1+4) may be comprised as Indopacific superprovince (called Indo-Westpacific by EKMAN 1935 and eotropical by SCHILDER 1956). The temperate South African province of EKMAN has been united with the tropical Indian province (1) for several reasons.

3—The regions usually extending 3,000 to 5,000 kilometers (SCHILDER 1939, p. 223, map 1 and 2) have been expressed by compound numbers the first digit of which indicates the province, the second digit indicates the relative place of the region within this province. The arrangement of the nine littoral provinces and 53 zoogeographical regions of the globe has been illustrated in the map (fig. 1).

This systematic meaning of figures and its invariable use will permit remembering the numbers of regions far more easily than the rather arbitrary arrangement of numbers published by the Challenger Society (BORRADAILE 1914).

4—However, as errors frequently happen in writing or printing digits, it seems advisable (but not necessary) to add to each number the abbreviation of the name of the region, expressed by the three first letters printed in capitals (so that they cannot be confused with abbreviations of the areas, see below). The abbreviations of the 33 regions inhabited by Cypraeidae, which will be explained in the list of areas, are as follows:

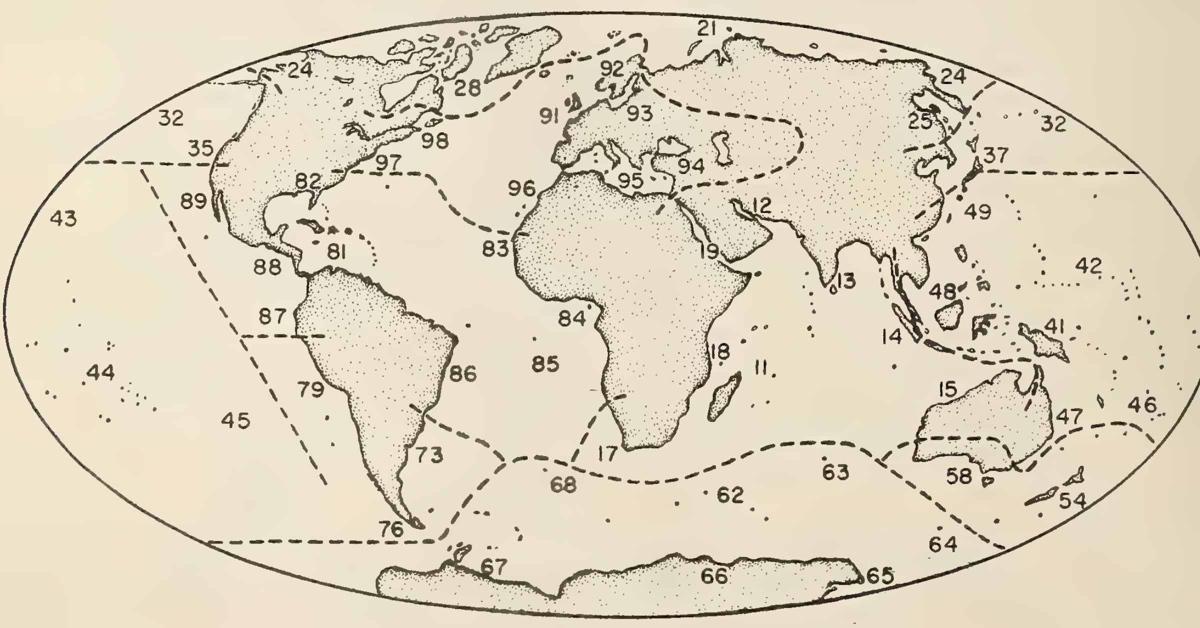

Figure 1: The littoral provinces and zoogeographical regions.

35 ORE		96 CAN	95 MED			37 JAP		
89 CAL	82 FLO	83 SEN	19 ERY	12 PER	13 IND	49 RYU	42 MIC	43 HAW
88 PAN	81 ANT	84 GUI	18 ZAN	11 LEM	14 SUM	48 MAL	41 MEL	44 POL
87 ECU	86 BRA	85 ATL	17 CAP		15 DAM	47 QUE	46 FIJ	45 RAP
	73 ARG				58 TAS	54 ZEA		

5—The restriction of habitat to a general part of the region may be designated by a third digit added as an exponent.

6—But if a still greater accuracy in fixing the distribution of a species is desired, one indicates the areas the diameter of which is about one thousand kilometers ("Gebiete" in Schilder 1941) by a small letter mostly adopted from my last catalogue (Schilder 1941, p. 63-64): these letters correspond to the initial letter of a generally well known central place, island, etc. within the area, as explained in the following list.

7—Whenever one wants to designate the restricted occurrence within such a small area, one can add to the letters some exponential digits indicating the general direction within the area.

The 160 areas inhabited by living true cowries (Cypraeidae, according to Schilder 1938/39 and 1941) will be enumerated in the following list. They have been arranged generally so that neighbouring areas follow each other: we begin with West America, East America, Europe, and West Africa, always from north to south, we continue with the Indian Ocean from South and East Africa to South Asia and Australia, then with the Western border of the Pacific from Melanesia to Japan, and we end with the central Pacific islands. The geographical relation of each area to the others has been shown in the map (fig. 2); the affinity of the cowrie faunas in these areas has been discussed by Schilder 1943.

In this list the left column contains the figures and letters by which the provinces, regions, and areas have been abbreviated in this paper. The central column indicates the names of provinces and regions (including their abbreviation by three capitals), as well as several localities, islands, etc. within each area without indicating its exact limits; the capital of a locality corresponding to the abbreviation of the area has been printed in *italics*. The figures of the right column indicate the average temperature of the surface of the sea in the coldest month (February or August) in centigrades according to the maps published by G. Schott (1926, 1935).

LIST OF THE AREAS INHABITED BY LIVING CYPRAEIDAE

3 North Pacific province (see also below)

35	ORE = Oregonian region	
35f	San *F*rancisco: C. Mendocino to Obispo	10-12

8 Western (Atlanto-American) province

89	CAL = Californian region	
89d	San *D*iego: Santa Rosa to Cedros Is.	13-18
89c	*C*ape San Lucas: Magdalena Bay to San José	19-21
89g	*G*ulf of California north of the Tropic	18-21
89m	*M*azatlan and Tres Marias Is.	22-24
89r	*R*evilla Gigedo Is.	23-24
88	PAN = Panamic region	
88c	*C*lipperton Island	27-28
88a	*A*capulco: Manzanillo to Tehuantepec	24-27
88s	San *S*alvador, San José to Coiba Island	26-28

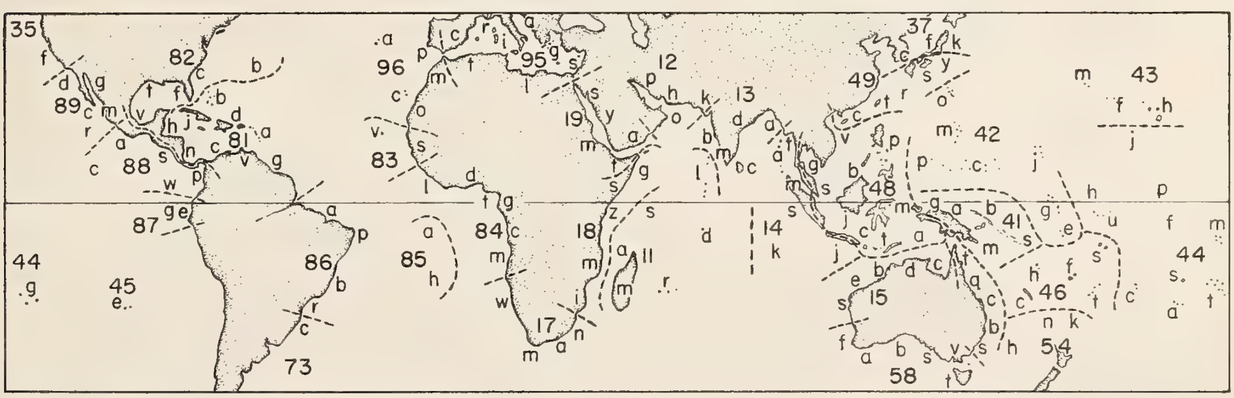

Figure 2: Geographical relation of the areas to each other.

88p	Gulf of *P*anama, Esmeraldas	24-26
88w	Cocos Island (*W*afer Bay)	26-27
87	ECU = Ecuadorian region	
87e	*E*cuador, North Peru: Manta to Sechura Bay	17-23
87g	*G*alapagos Islands	20-22
82	FLO = Floridan region	
82b	*B*ermudas	20
82c	*C*arolina: Cape Hatteras to Georgia	15-19
82f	*F*lorida (East and West Coast), Key West	20-24
82t	Alabama to *T*exas	20-22
82v	*V*era Cruz: Tampico to Progreso	23-26
81	ANT = Antillean (Caribbean) region	
81j	Cuba, Cayman Is., *J*amaica	25-26
81b	*B*ahama Islands	24-25
81d	San *D*omingo (Hispaniola), Porto Rico	25-26
81a	Lesser *A*ntilles: Saint Thomas to Grenada	26
81h	Arrowsmith Bank to *H*onduras	26
81n	*N*icaragua to Colon	26
81c	*C*olombia from Darien to Rio Hacha	26
81v	*V*enezuela, Curaçao, Trinidad	26
81g	*G*uiana to Amazonas River	26-27
86	BRA = Brasilian region	
86a	*A*mazonas River to Parnahyba	25-26
86p	*P*ernambuco to Fortaleza, Fernando Noronha	24-26
86b	*B*ahía: Aracaju to Abrolhas	24-25
86r	*R*io de Janeiro: Victoria to Santos	18-23
7 South American province		
73	ARG = Argentinian region	
73c	Paranagua to Santa *C*atharina	16-18
9 North Atlantic province		
95	MED = Mediterranean region	
95c	Gibraltar to *C*atalonia, Balearic Is.	13-14
95r	*R*iviera: Southern France to Spezia	10-13
95i	S. W. *I*taly, Sardinia, Sicily, Malta	13-14
95a	*A*driatic Sea north of Otranto and Valona	12-13
95g	*G*reece to Dardanelles, Crete, Rhodos	14-16
95s	*S*yria: Adalia to Alexandria, Cyprus	16-17
95l	Cyrenaica and *L*ibya	15-17
95t	*T*unisia, Algeria, North coast of Morocco	14
96	CAN = Canarian region	
96p	*P*ortugal to Cape Tarifa	13-15
96m	West coast of *M*orocco: Tangiers to Ifni	15-17
96a	*A*zores	15-16
96c	Madeira, *C*anary Islands	17-18
96o	Rio de *O*ro: Bojador to St. Louis	13-15
8 Western (Atlanto-American) province (continued)		
83	SEN = Senegal region	
83v	Cape *V*erde Islands	21-22
83s	*S*enegal: Dakar to Konakri	19-24
84	GUI = Guinean region	
84l	*L*iberia: Freetown to Ivory Coast	25
84d	*D*ahomey: Ghana to Nigeria	25
84t	São *T*homé: Principe to Annobon	24-25
84g	Cameroons, Fernando Poo, *G*abun	24-25
84c	*C*ongo River: Loango to Benguella	18-23
84m	*M*ossamedes to Cunene River	16-18
85	ATL = South Atlantic region	
85a	*A*scension Island	23-24
85h	St. *H*elena Island	20
1 Indian province		
17	CAP = Cape (South African) region	
17w	*W*alvis Bay to Saldanha Bay	13-16
17m	Cape Town to *M*ossel Bay, Agulhas Bank	15-17
17a	*A*lgoa Bay to East London	18-20
17n	Pondoland, *N*atal, Zululand	20-21
18	ZAN = Zanzibarian (East African) region	
18i	*I*nhambane: Delagoa Bay to Beira	22-23
18m	*M*ozambique: Quelimane to Querimba	24
18z	Tanganyika, *Z*anzibar, Kenya	25
18s	*S*omaliland: Kismaju to Obbia	23-25
18g	Hafun, Cape *G*uardafui, Socotra Island	22-25
11	LEM = Lemurian region	
11a	Comoro, *A*ldabra, Glorieuses, Providence	24-25
11m	Nosi Bé, *M*adagascar, Europa Is.	22-24
11r	*R*éunion, Mauritius, Rodriguez	22-23
11c	*C*argados Carajos to Galega Is.	24-25
11s	Coetivy Is., Amirantes, *S*eychelles	25-26
11d	Chagos Archipelago (*D*iego Garcia)	26-27
11l	Maldive Is., Minicoy, *L*accadive Is.	27-28
19	ERY = Erythraean (Red Sea) region	
19t	*T*ajura: Berbera to Perim Is.	25-26
19m	*M*assawa: Assab to Port Sudan	21-25
19s	Kosseir, *S*uez, Tor, Aqaba	19-21
19y	Hejaz, Jidda, *Y*emen, Mocha	22-26
19a	*A*den to Makalla	20-25
12	PER = Persian region	
12o	Kuria Muria Is. to *O*man	22-23
12p	*P*ersian Gulf west of 55° E.	15-21
12h	Strait of *H*ormuz, Mekran Coast	21-22
12k	*K*arachi to Port Okha	22-23
13	IND = Indian region	
13b	*B*ombay: Cambay Gulf to Goa	23-26
13m	*M*alabar Coast: Mangalore to Tuticorin	26
13c	*C*eylon and Adams Bridge	27
13d	*D*eccan: Karikal to Orissa	25-27
13a	Calcutta to *A*rakan	24-26
14	SUM = Sumatran region	
14t	*T*enasserim: Mergui Archipelago to Salang Is.	26-28
14m	*M*alacca Strait: Penang to Medan	28
14a	*A*ndaman Is., Nicobar Is.	27
14s	West coast of *S*umatra and adjacent islands	28

14j	South coast of *J*ava, Christmas Is.	26-28
14k	Cocos *K*eeling Is.	26
15	DAM = Dampierian (North West Australian) region	
15c	Gulf of *C*arpentaria	25
15d	*D*arwin: Wessel Is. to Wyndham	26
15b	Cape Londonderry to *B*roome, Rowley Shoals	23-26
15e	Shellborough to *E*xmouth Gulf, Dampier Is.	22-23
15s	*S*hark Bay to Geraldton, Abrolhos Archipelago	19-21

5 South Australian province

58	TAS = Tasmanian (South Australian) region	
58f	*F*remantle: Cervantes Is. to Cape Leeuwin	17-18
58a	*A*lbany: Flinders Bay to Esperance	14-17
58b	Great Australian *B*ight around Eucla	14
58s	*S*pencer Gulf to Beachport	13-14
58v	*V*ictoria: Portland to Montague Island	13-14
58t	King Is., Flinders Is., *T*asmania	11-12
54	ZEA = Neozelanic region (see WHITLEY 1937, p. 199)	
54k	*K*ermadec Islands	17-18
54n	*N*orfolk Island	18-19
54h	Lord *H*owe Islands, Middleton Reef	17-18

4 Pacific province

47	QUE = Queensland (North East Australian) region	
47s	*S*ydney: Ulladulla to Port Stephens	15-17
47b	*B*risbane: Sugar Loaf Point to Fraser Is.	18-19
47c	*C*apricorn Is.: Hervey Bay to Whitsunday Is.	19-20
47q	North *Q*ueensland: Port Denison to C. Melville	20-23
47t	*T*orres Strait: C. Melville to Fly River	23-26
46	FIJ = Fijian (Southern Melanesian) region	
46c	Chesterfield Is., New *C*aledonia, Loyalty Is.	22-24
46h	New *H*ebrides	23-26
46f	*F*iji Islands	24-25
46t	*T*onga (Friendly) Is., Niue (Savage) Is.	22-24
46s	*S*amoan Islands, Wallis Is.	27-28
41	MEL = (Northern) Melanesian region	
41s	Santa Cruz Is., *S*olomon Is., Nissan Is.	27-28
41b	*B*ismarck Archipelago, Admiralty Is.	28
41m	Port *M*oresby to Louisiade Archipelago	27
41a	*A*strolabe Bay: Huon Gulf to Aitapé	28
41g	Humboldt Bay to *G*eelvink Bay, Mapia Is.	28
48	MAL = Malayan (Indonesian) region	
48m	N.W. New Guinea, *M*oluccas, North Celebes	28
48a	S. W. New Guinea, *A*ru Is., Kei Is., Timorlaut	26-27
48t	*T*imor to Bali	26-27
48c	South *C*elebes, S.E. Borneo, Tiger Is.	27
48j	Bawean Is., North coast of *J*ava	27
48s	Belitong, S.E. Sumatra, *S*ingapore, S.W. Borneo	27
48g	*G*ulf of Siam: Thailand to Pulo Condor	25-28
48b	Natuna Is., Sarawak, N. *B*orneo, Tizard Bank	26-27
48p	Palawan, *P*hilippine Is.	26-27
48v	*V*ietnam (Annam, Tongking) Paracel Reefs	20-24
49	RYU = Ryukyu region (see NOMURA & HATAI 1936)	
49c	*C*hina from Hainan to Amoy	12-20
49t	Pescadores Is., *T*aiwan (Formosa)	18-24
49r	*R*yukyu Is.: Sakishima to Tanegashima	18-23
49s	*S*hikoku: Kyushu to Kii coast	14-16
49y	*Y*okohama: Ise to Chiba, Hachijoshima	12-14

3 North Pacific province (continued)

37	JAP = (Northern) Japanese region (see NOMURA & HATAI 1936)	
37k	*K*asima and East coast of North Hondo	9-11
37f	*F*ukui: Tsushima Strait to Echigo	10-13
37c	South coast of *C*orea	10

4 Pacific province (continued)

42	MIC = Micronesian region	
42o	*O*gasawara Is. (Bonin Is.), Volcano Is.	20-22
42m	*M*arianas Islands, Guam Is.	25-27
42p	Yap Is., *P*alau Is.	27-28
42c	*C*aroline Is.: Uleay (Oreai) to Kusaie	27-28
42j	Marshall Islands around *J*aluit	27-28
42g	*G*ilbert Is. (Kingsmill Is.), Nauru Is.	28
42e	*E*llice Islands, Rotuma Is.	28
44	POL = Polynesian region	
44h	*H*owland Is., Baker Is., Phoenix Is.	27-28
44u	*U*nion (Tokelau) Is. to Suvorov Is.	26-27
44c	*C*ook Islands	23-24
44a	*A*ustral Is. (Tubuai Is.)[1]	20-21
44s	*S*ociety Is.: Raiatea to Tahiti	24-25
44t	*T*uamotu Is.: Makatea to Pinaki	24-26
44g	*G*ambier Is.: Marutea du Sud to Henderson Is.	22-24
44m	*M*arquesas Islands	26
44f	*F*lint Is., Manahiki Is. to Malden Is.	26-27
44p	Line Is.: Jarvis Is. to *P*almyra Is.	26
44j	*J*ohnston Island	25
45	RAP = Rapanuian Region	
45e	*E*aster Island (Rapanui)	19-20
43	HAW = Hawaiian region	
43h	*H*awaii to Kauai	23-24
43f	*F*rench Frigate Shoals, Laysan Is.	21-22
43m	*M*idway Is.: Pearl-Hermes Reef to Kure Is.	19-21

The following list contains the living cowrie species and several degrees of subspecific rank, i. e.

(p) = prospecies of almost specific rank,
(s) = morphologically well recognizable subspecies (races),
(m) = morphologically well recognizable local mutants,

[1] As only one cowrie species (*Luria isabella lekalekana* LADD) is known from these rarely visited islands, the area generally has been treated in the list as if it were non existing or united with 44c.

(c) = clines which are morphologically recognizable in extreme areas only, but elsewhere gradually pass into the typical species,

(i) = geographically separated, but otherwise hardly recognizable infra-species;

the other "races" distinguished by SCHILDER 1938/39 have been suppressed, as they need further research concerning both characters and exact range.

The arrangement of species agrees with my latest catalogue (SCHILDER 1941) except if recent anatomical research made changes necessary.

The areas inhabited have been arranged according to the preceding list. The regions have been indicated both by the abbreviation consisting of three capitals and by the number composed of the digits of the province and the region within; these figures are followed by the small letters indicating the areas of the region in which the species actually has been found (the letter x indicates occurrence in the region without exact area known). These letters have been replaced by an asterisk (*) if evidently all areas of the region are inhabited, even if less common species have not yet been reported from less investigated areas which are surrounded by inhabited areas; if, however, some few areas situated at the border of the distribution of the species evidently are not any more inhabited because of unfavorable conditions chiefly in temperature, the letters of such excluded areas have been added to the asterisk separated by a minus (—). Doubtful occurrence has been put in parentheses; probably artificial introduction by man (as dead or even living specimens) have been marked by a preceding cross (×) thus becoming separated from the genuine distribution. Evidently erroneous indications of habitat have been omitted.

CYPRAEIDAE GRAY, 1824

Cypraeorbinae SCHILDER, 1939

Bernaya JOUSSEAUME, 1884

(*Protocypraea* SCHILDER, 1927)

teulèrei (CAZENAVETTE, 1846) ERY: 19my^{6}a PER: 12h^8(op)

fultoni (SOWERBY, 1903) CAP: 17n(a)

(*Bernaya* JOUSSEAUME, 1884)

catei SCHILDER, 1963 DAM: 15s^7

Zoila JOUSSEAUME, 1884

decipiens (SMITH, 1880) DAM: 15bes^2

venusta (SOWERBY, 1846) DAM: 15e (TAS: 58f^2)

(s) *episema* IREDALE, 1939 TAS: 58f^0

(m) *sorrentensis* SCHILDER, 1963 (DAM: 15s^7) TAS: 58f^2

thersites (GASKOIN, 1849) TAS: 58s

(c) *contraria* IREDALE, 1935 TAS: 58b

friendii (GRAY, 1831) TAS: 58f

(c) *vercoi* SCHILDER, 1930 TAS: 58a

marginata (GASKOIN, 1849) DAM: 15s^7 TAS: 58f^2(a^8)

rosselli (COTTON, 1948) TAS: 58f

Siphocypraea HEILPRIN, 1887

(*Akleistostoma* GARDINER, 1948)

mus (LINNAEUS, 1758) ANT: 81cv(a)

Cypraeinae SCHILDER, 1939

(Cypraeini SCHILDER, 1927)[2]

Trona JOUSSEAUME, 1884

stercoraria (LINNAEUS, 1758) SEN: 83s GUI: 84*

Macrocypraea SCHILDER, 1930

zebra (LINNAEUS, 1758) FLO: 82*(—b) ANT: 81* (—g)

(i) *dissimilis* (SCHILDER, 1924) BRA: 86pbr ARG: 73c

cervus (LINNAEUS, 1771) FLO: 82* ANT: 81j(da^2)

(p) *cervinetta* (KIENER, 1843) CAL: 89cgm PAN: 88*—cw ECU: 87* × MIC: 42j

Mauritia TROSCHEL, 1863

valentia (PERRY, 1811) QUE: 47t

mappa (LINNAEUS, 1758) (ZAN: 18z) (LEM: 11m) DAM: 15c QUE: 47cqt FIJ: 46* MEL: 41* MAL: 48*—gv RYU: 49tr MIC: 42*—o POL: 44*—gj

(c) *geographica* SCHILDER & SCHILDER, 1933 SUM: 14aj(ms)

(s) *alga* (PERRY, 1811) ZAN: 18z LEM: 11* (ERY: 19tm) (IND: 13c)

eglantina (DUCLOS, 1833) SUM: 14j(ms) DAM: 15*—s ZEA: 54h QUE: 47*—s FIJ: 46*—t MEL: 41* MAL: 48* -gbv RYU: 49tr(c) MIC: 42cjg(e)

[2] Ed. note: As we have no typographical provision for Dr. Schilder's taxon, the "infrafamily", we now introduce this type style to designate this taxon: (Infrafamily). While each lower taxon is indented one full space (an m-space), the infrafamily is indented only one half space more than the Subfamily.

histrio (Gmelin, 1791) (CAP: 17n) ZAN: 18imz LEM: 11* IND: 13* SUM: 14* —tm
(c) *westralis* (Iredale, 1935) DAM: 15: dbe
grayana Schilder, 1930 ZAN: 18s²g (LEM: 11s) ERY: 19* PER: 12* IND: 13b
arabica (Linnaeus, 1758) SUM: 14* DAM: 15* ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49* MIC: 42*
(c) *dilacerata* Schilder & Schilder, 1939 IND: 13*
(s) *immanis* Schilder & Schilder, 1939 CAP: 17an ZAN: 18*—g LEM: 11*
maculifera Schilder, 1932 FIJ: 46sf(cht) (MAL: 48p) RYU: 49trs MIC: 42*—o POL: 44* HAW: 43*—m ×PAN: 88cs
depressa (Gray, 1824) FIJ: 46* MEL: 41b MAL: 48p (RYU: 49trs) MIC: 42*—o POL: 44*—j × PAN: 88c
(i) *dispersa* Schilder & Schilder, 1939 ZAN: 18z LEM: 11sl IND: 13mc SUM: 14sjk
mauritiana (Linnaeus, 1758) (CAP: 17an) ZAN: 18* LEM: 11* ERY: 19tma (PER: 12o)
(i) *regina* (Gmelin, 1791) IND: 13*—b SUM: 14* DAM: 15b QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49*(—c) MIC: 42* POL: 44* HAW: 43*
scurra (Gmelin, 1791) ZAN: 18mz LEM: 11* IND: 13mc SUM: 14asj DAM: 15x
(s) *indica* (Gmelin, 1791) (SUM: 14j) QUE: 47* FIJ: 46* MEL: 41* MAL: 48⁴(*) RYU: 49tr MIC: 42*—o POL: 44* HAW: 43* × PAN: 88c

Talparia Troschel, 1863

talpa (Linnaeus, 1758) CAP: 17n ZAN: 18* LEM: 11* ERY: 19* PER: 12o IND: 13mcd SUM: 14tasj DAM: 15*—s QUE: 47cqt FIJ: 46* MEL: 41* MAL: 48*—sgv RYU: 49trs MIC: 42*—o POL: 44* HAW: 43*
exusta (Sowerby, 1832) ERY: 19*—s(a)

Cypraea Linnaeus, 1758

tigris Linnaeus, 1758 CAP: 17n ZAN: 18* LEM: 11* ERY: 19ta
(i) *pardalis* Shaw, 1795 IND: 13*—b SUM: 14* DAM: 15bes ZEA: 54h QUE: 47cqt FIJ: 46* MEL: 41* MAL: 48*—g RYU: 49*(—y) MIC: 42* POL: 44*—j
(c) *schilderiana* Cate, 1961 POL: 44j HAW: 43*
(hybrid) *catulus* Schilder, 1924, 1962 ERY: 19a(t)
pantherina Solander, 1786 ERY: 19*

Lyncina Troschel, 1863

aurantium (Gmelin, 1791) FIJ: 46* MEL: 41sb MAL: 48p⁶ MIC: 42*—o POL: 44cst
broderipi (Sowerby, 1832) CAP: 17n (LEM: 11m)
nivosa (Broderip, 1827) (LEM: 11r) IND: 13cd SUM: 14t
leucodon (Broderip, 1828) LEM: 11d
argus (Linnaeus, 1758) ZAN: 18z LEM: 11* IND: 13cd SUM: 14asj DAM: 15es² QUE: 47cqt FIJ: 46* MEL: 41* MAL: 48*—g RYU: 49tr MIC: 42*—o POL: 44up
lynx (Linnaeus, 1758) CAP: 17n ZAN: 18* LEM: 11* ERY: 19* IND: 13cd SUM: 14* DAM: 15*—s ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49*—cy MIC: 42*—o POL: 44* HAW: 43*
vitellus (Linnaeus, 1758) CAP: 17an ZAN: 18* LEM: 11* (ERY: 19a) IND: 13cd SUM: 14* DAM: 15* (TAS: 58f) ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49*—c MIC: 42* POL: 44*—g HAW: 43* × PAN: 88c
camelopardalis (Perry, 1811) ERY: 19*—s(a)
reevei (Sowerby, 1832) TAS: 58fabs
ventriculus (Lamarck, 1810) FIJ: 46* MEL: 41sb MAL: 48p MIC: 42*—o POL: 44*—j
schilderorum (Iredale, 1939) FIJ: 46cfs (MAL: 48p) MIC: 42*—o POL: 44* HAW: 43* × PAN: 88c
(i) *kuroharai* (Kuroda & Habe, 1961) RYU: 49rs
sulcidentata (Gray, 1824) HAW: 43*
carneola (Linnaeus, 1758) CAP: 17an ZAN: 18* LEM: 11* ERY: 19* PER: 12* IND: 13* SUM: 14*-tk DAM: 15* ZEA: 54kh QUE: 47* FIJ: 46*

MEL: 41* MAL: 48* RYU: 49*-c MIC: 42* POL: 44* HAW: 43h
(m) *titan* Schilder & Schilder, 1962 ZAN: 18mz LEM: 11mr
(m) *leviathan* (Schilder & Schilder, 1937) (POL: 44*-hu) HAW: 43hf

(Luriini Schilder, 1932)

Chelycypraea Schilder, 1927

testudinaria (Linnaeus, 1758) (QUE: 47*-s FIJ: 46* MEL: 41* MAL: 48mp RYU: 49trs MIC: 42*-o POL: 44*-j
(i) *ingens* (Schilder & Schilder, 1938) (CAP: 17n) ZAN: 18mz LEM: 11* IND: 13c

Luria Jousseaume, 1884

tessellata (Swainson, 1822) (POL: 44h) HAW: 43*
pulchra (Gray, 1828) ERY: 19tma [s=*fossil only*] PER: 12oph
isabella (Linnaeus, 1758) CAP: 17an ZAN: 18* LEM: 11* ERY: 19* IND: 13c
(c) *lekalekana* (Ladd, 1934) SUM: 14*-tm DAM: 15* ZEA: 54kh QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49*-c MIC: 42* POL: 44*(-j)
(c) *controversa* (Gray, 1824) HAW: 43*
(p) *mexicana* (Stearns, 1893) CAL: 89cgmr PAN: 88cw (ECU: 87g)
cinerea (Gmelin, 1791) FLO: 82* ANT: 81* BRA: 83*-r
lurida (Linnaeus, 1758) MED: 95* CAN: 96* SEN: 83* GUI: 84*-m
(i) *oceanica* Schilder, 1930 ATL: 85*

Nariinae Schilder, 1932

(Pustulariini Schilder, 1932)

Pustularia Swainson, 1840

(*Annepona* Iredale, 1939)

mariae Schilder, 1927 FIJ: 46* MEL: 41sb MAL: 48p RYU: 49r MIC: 42*-o POL: 44* HAW: 43h

(*Pustularia* Swainson, 1840)

globulus (Linnaeus, 1758) IND: 13c SUM: 14asj DAM: 15s[2] QUE: 47xt FIJ: 46*-t MEL: 41* MAL: 48*-g RYU: 49trs MIC: 42*-o (POL: 44p)
(s) *brevirostris* Schilder & Schilder, 1938 (CAP: 17n) ZAN: 18z LEM: 11*
(p) *nov. prospec.* HAW: 43h
margarita (Dillwyn, 1817) FIJ: 46*-t MEL: 41sba MAL: 48p MIC: 42* POL: 44*-gmj
(i) *tricornis* (Jousseaume, 1874) LEM: 11r(s) (ERY: 19a)
cicercula (Linnaeus, 1758) SUM: 14tasj DAM: 15e QUE: 47c(s) FIJ: 46*(-s) MEL: 41*-m MAL: 48*-v RYU: 49trs MIC: 42c POL: 44c
(i) *lienardi* (Jousseaume, 1874) ZAN: 18z LEM: 11rsd ERY: 19a
(s) *tetsuakii* Kira, 1959 RYU: 49r HAW: 43*
bistrinotata Schilder & Schilder, 1937 (IND: 13c) SUM: 14*-t DAM: 15c (ZEA: 54h) QUE: 47* FIJ: 46* MEL: 41* MAL: 48-v RYU: 49trs[6] MIC: 42* POL: 44* HAW: 43*

(*Ipsa* Jousseaume, 1884)

childreni (Gray, 1825) FIJ: 46* MEL: 41sba MAL: 48gbp RYU: 49trs MIC: 42*-o POL: 44* HAW: 43*
(i) *lemurica* Schilder & Schilder, 1938 LEM: 11rd SUM: 14j[6]

Propustularia Schilder, 1927

surinamensis (Perry, 1811) ANT: 81av[2](g)

(Nariini Schilder, 1932)

Monetaria Troschel, 1863

annulus (Linnaeus, 1758) CAP: 17an(m) ZAN: 18* LEM: 11* ERY: 19* PER: 12o IND: 13* SUM: 14* DAM: 15*-es ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49*-c JAP: 37kf MIC: 42* POL: 44hucfp
(c) *obvelata* (Lamarck, 1810) POL: 44cstgmf
moneta (Linnaeus, 1758) CAP: 17man ZAN: 18* LEM: 11* ERY: 19* PER: 12o IND: 13* SUM: 14* DAM: 15* ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49*-c JAP: 37f MIC: 42* POL: 44* HAW: 43h × PAN: 88cw × ECU: 87g

Naria Broderip, 1837

irrorata (Gray, 1828) FIJ: 46s(c) MEL: 41sb MIC: 42*-op POL: 44*-j

Erosaria Troschel, 1863

(*Paulonaria* Iredale, 1930)

dillwyni (Schilder, 1922) FIJ: 46ft^{4}s (MIC: 42mg) POL: 44ucstg
becki (Gaskoin, 1836) (FIJ: 46c) MEL: 41bg MAL: 48m^{2}p RYU: 49trs MIC: 42*-o POL: 44u (HAW: 43h)
macandrewi (Sowerby, 1870) ERY: 19t^{2}ms

(*Erosaria* Troschel, 1863)

labrolineata (Gaskoin, 1849) SUM: 14j DAM: 15e ZEA: 54h QUE: 47* FIJ: 46*-t MEL: 41* MAL: 48*-v RYU: 49*(-c) MIC: 42* POL: 44u
cernica (Sowerby, 1870) (CAP: 17n) LEM: 11rd
(i) *viridicolor* (Cate, 1962) DAM: 15es(c) (TAS: 58f)
(s) *tomlini* Schilder, 1930 ZEA: 54knh QUE: 47sb FIJ: 46c(h)
(s) *ogasawarensis* Schilder, 1944 RYU: 49rsy MIC: 42o POL: 44h HAW: 43*
citrina (Gray, 1825) CAP: 17an × LEM: 11m
gangranosa (Dillwyn, 1817) (CAP: 17n) ZAN: 18z(m) LEM: 11l ERY: 19ta IND: 13mc(a) SUM: 14asj MEL: 41g MAL: 48mt^{8}cjs
boivini (Kiener, 1843) SUM: 14j MAL: 48*-av RYU: 49sy
(p) *ostergaardi* (Dall, 1921) HAW: 43*
helvola (Linnaeus, 1758) CAP: 17n ZAN: 18* LEM: 11* ERY: 19ta(m) IND: 13cd(m) SUM: 14*-t DAM: 15* TAS: 58fa^8 ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49*-c JAP: 37f MIC: 42* POL: 44* HAW: 43* × PAN: 88c
(c) *meridionalis* Schilder & Schilder, 1938 CAP: 17an
caputserpentis (Linnaeus, 1758) CAP: 17an ZAN: 18*-sg LEM: 11* IND: 13mcd SUM: 14* DAM: 15*-s ZEA: 54kn (QUE:47t) FIJ46* MEL:41* MAL: 48* RYU: 49* JAP: 37f MIC:42* POL:44*-j × PAN:88cs
(c) *kenyonae* Schilder & Schilder, 1938 DAM: 15es TAS: 58fa
(c) *caputanguis* (Philippi, 1849) ZEA: 54h QUE: 47sbc
(c) *caputophidii* Schilder, 1927 HAW: 43*
caputdraconis (Melvill, 1888) RAP: 45e
albuginosa (Gray, 1825) CAL: 89*-d PAN: 88cw(sp) ECU: 87*
spurca (Linnaeus, 1758) MED: 95* CAN: 96* SEN: 83* GUI: 84*-m
(s) *sanctaehelenae* Schilder, 1930 ATL: 85*
(p) *acicularis* (Gmelin, 1791) FLO: 82*-bc ANT: 81*-hnc BRA: 86*
poraria (Linnaeus, 1758) ZAN:18z LEM: 11* IND: 13c SUM: 14sj DAM:15e
(i) *scarabaeus* (Bory, 1827) ZEA: 54kh QUE: 47s FIJ: 46* MEL: 41sba MAL: 48mbp RYU: 49*-c MIC: 42* POL: 44*-gm HAW: 43*
erosa (Linnaeus, 1758) CAP: 17an ZAN: 18*-sg LEM: 11* IND: 13cd SUM:14* DAM: 15*-s ZEA: 54k QUE:47*-s FIJ: 46* MEL: 41* MAL: 48*-v RYU: 49* MIC: 42* POL: 44*-m HAW: 43h
(c) *pulchella* Coen, 1949 ZEA: 54h QUE: 47sb
(p) *nebrites* (Melvill, 1888) ZAN: 18zsg ERY: 19* PER: 12ohk IND: 13b
ocellata (Linnaeus, 1758) LEM: 11l (ERY: 19ta) PER: 12hk IND: 13* SUM: 14j
marginalis (Dillwyn, 1827) CAP: 17an ZAN: 18* LEM: 11rs ERY: 19a PER: 12o
miliaris (Gmelin, 1791) SUM:14j DAM: 15* QUE: 47* MEL: 41mg MAL: 48* RYU: 49* MIC: 42p × ZAN: 18z
(s) *eburnea* (Barnes, 1824) QUE: 47bcq FIJ: 46chf(t) MEL: 41* (MAL: 48p)
(p) *lamarcki* (Gray, 1825) CAP: 17an ZAN: 18*-g LEM: 11am
(c) *redimita* (Melvill, 1888) LEM: 11*-a PER: 12k IND: 13*-a SUM: 14tmas
turdus (Lamarck, 1810) ZAN: 18z^{2}sg ERY: 19*
(c) *winckworthi* Schilder & Schilder, 1938 PER: 12* × CAP: 17a
guttata (Gmelin, 1791) FIJ: 46h MEL: 41sb MIC: 42c
(i) *azumai* Schilder, 1960 RYU: 49s

Staphylaea Jousseaume, 1884

staphylaea (Linnaeus, 1758) CAP: 17an ZAN: 18* LEM: 11* (ERY: 19a) IND: 13c(b) SUM: 14tasj DAM: 15be ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48*-v RYU: 49*-c MIC: 42*-o POL: 44ucst

limacina (Lamarck, 1810) CAP: 17n ZAN: 18imz LEM: 11*-l IND: 13c SUM: 14sj DAM: 15bes ZEA: 54h QUE: 47*-s FIJ: 46* MAL: 48*-agv RYU: 49* JAP: 37f MIC: 42m
semiplota (Mighels, 1845) HAW: 43*

Nuclearia Jousseaume, 1884

nucleus (Linnaeus, 1758) ZAN: 18* LEM: 11* ERY: 19* IND: 13c SUM: 14*-k DAM: 15e ZEA: 54h QUE: 47cqt FIJ: 46* MEL: 41* MAL: 48* RYU: 49* MIC: 42* POL: 44*-j HAW: 43* [*rare*]
(p) *granulata* (Pease, 1862) POL: 44j HAW: 43*

Cypraeovulinae Schilder, 1930

(Zonariini Schilder, 1932)

Schilderia Tomlin, 1930

achatidea (Sowerby, 1837) MED: 95crit(gl)
(i) *inopinata* Schilder, 1930 GUI: 84m
langfordi (Kuroda, 1938) RYU: 49s
(s) *nov. subspec.* QUE: 47b
hirasei (Roberts, 1913) RYU: 49s
teramachii (Kuroda, 1938) RYU: 49s

Zonaria Jousseaume, 1884

(*Zonaria* Jousseaume, 1884)

zonaria (Gmelin, 1791) CAN: 96o SEN: 83s GUI: 84*-m
(m) *gambiensis* (Shaw, 1909) SEN: 83s
picta (Gray, 1824) (CAN: 96c) SEN: 83*
sanguinolenta (Gmelin, 1791) SEN: 83s
pyrum (Gmelin, 1791) MED: 95* CAN: 96*(-a) SEN: 83s
(c) *senegalensis* Schilder, 1928 SEN: 83s
(i) *angolensis* (Odhner, 1923) GUI: 84m
(p) *petitiana* (Crosse, 1872) SEN: 83s (GUI: 84tg)
annettae (Dall, 1909) CAL: 89cgm
(p) *aequinoctialis* Schilder, 1933 ECU: 87e

(*Neobernaya* Schilder, 1927)

spadicea (Swainson, 1823) ORE: 35f[6] CAL: 89d

(*Pseudozonaria* Schilder, 1927)

robertsi (Hidalgo, 1906) CAL: 89cgm PAN: 88asp ECU: 87e

nigropunctata (Gray, 1828) ECU: 87*
arabicula (Lamarck, 1810) CAL: 87cgm PAN: 88asp ECU: 87*

(Cypraeovulini Schilder, 1941)

Cypraeovula Gray, 1824

(*Luponia* Broderip, 1837)

fuscorubra (Shaw, 1909) CAP: 17w[6]ma
fuscodentata (Gray, 1825) CAP: 17ma
algoensis (Gray, 1825) CAP: 17ma
edentula (Gray, 1825) CAP: 17a(n[6])

(*Cypraeovula* Gray, 1824)

amphithales (Melvill, 1888) CAP: 17a(n)
capensis (Gray, 1828) CAP: 17a(n)

Umbilia Jousseaume, 1884

armeniaca (Verco, 1912) TAS: 58b
(p) *hesitata* (Iredale, 1916) TAS: 58vt QUE: 47s

Notocypraea Schilder, 1927

pulicaria (Reeve, 1846) TAS: 58fa[8]
bicolor (Gaskoin, 1849) TAS: 58bsvt
(m) *wilkinsi* (Griffiths, 1959) TAS: 58v[1]
(c) *reticulifera* (Schilder, 1924) TAS: 58a
(i) *euclia* (Steadman & Cotton, 1946) TAS: 58b[8]
(s) *occidentalis* Iredale, 1935 TAS: 58f[8]
piperita (Gray, 1825) TAS: 58f[8]absv
(i) *dissecta* Iredale, 1931 TAS: 58v[4]
(s) *comptoni* (Gray, 1847) TAS: 58a[4]bsvt
(m) *casta* Schilder & Summers, 1963 TAS: 58s[6]
(c) *mayi* (Beddome, 1898) TAS: 58vt
angustata (Gmelin, 1791) TAS: 58svt
(i) *moelleri* (Iredale, 1931) TAS: 58v[4]
(p) *declivis* (Sowerby, 1870) TAS: 58v[8]t

(Erroneini Schilder, 1930)

Erronea Troschel, 1863

(*Gratiadusta* Iredale, 1930)

walkeri (Sowerby, 1832) LEM: 11csl SUM: 14as [j *fossil only*] DAM: 15cbe QUE: 47*(-s) (MEL: 41b) MAL: 48*-v RYU: 49r(s) Mic: 42c
(p) *bregeriana* (Crosse, 1868) FIJ: 46cf (MEL: 41m)
pyriformis (Gray, 1824) IND: 13cd SUM: 14tm QUE: 47cqt MAL: 48*-gbv
(c) *smithi* (Sowerby, 1881) DAM: 15dbe

pulchella (Swainson, 1823) MAL: 48p RYU: 49ctr
(s) *novaebritanniae* Schilder & Schilder, 1937 FIJ: 46f MEL: 41b
(s) *pericalles* (Melvill & Standen, 1904) ERY: tm^{6}a PER: 12oph
hungerfordi (Sowerby, 1888) RYU: 49sy
(s) *coucomi* Schilder, 1964 QUE: 47b
barclayi (Reeve, 1837) (CAP: 17n) LEM: 11d(r)

(*Adusta* Jousseaume, 1884)

xanthodon (Sowerby, 1832) QUE: 47*(-t)
vredenburgi Schilder, 1927 SUM: 14j MAL: 48t^{8}(m^{2})
pallida (Gray, 1828) PER: 12*-o IND: 13* SUM: 14tm MAL: 48s(g) × ERY: 19a
(c) *insulicola* Schilder & Schilder, 1938 SUM: 14s^{6} MAL: 48j
subviridis (Reeve, 1835) QUE: 47* FIJ: 46c
(p) *dorsalis* Schilder & Schilder, 1938 DAM: 15* (MAL: 48a)
onyx (Linnaeus, 1758) (SUM: 14j) MEL: 41g MAL: 48* RYU: 49* MIC: 42m
(s) *melanesiae* Schilder & Schilder, 1937 MEL: 41b
(p) *adusta* (Lamarck, 1810) ZAN: 18imz LEM: 11*-rd PER: 12*-o IND: 13* SUM: 14ta
(m) *nymphae* (Jay, 1850) LEM: 11rd

(*Erronea* Troschel, 1863)

ovum (Gmelin, 1791) SUM: 14sj DAM: 15b QUE: 47cqt MEL: 41* MAL: 48* RYU: ctr MIC: 42p
errones (Linnaeus, 1758) IND: 13*-ba SUM: 14*-k DAM: 15*-s ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48* RYU: 49* MIC: 42mpc(g) POL: 44c(p) (×) ZAN: 18z(s)
cylindrica (Born, 1778) SUM: 14sj QUE: 47*-s FIJ: 46h(c) MEL: 41* MAL: 48*-v RYU: 49tr(s) MIC: 42mp(g)
(s) *sowerbyana* Schilder, 1932 DAM: 15*-s
caurica (Linnaeus, 1758) CAP: 17an ZAN: 18* LEM: 11* ERY: 19* PER: 12* IND: 13*-da SUM: 14*-k DAM: 15* ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL:48* RYU: 49trs MIC: 42*-o POL: 44c

(*Melicerona* Iredale, 1930)

felina (Gmelin, 1791) CAP: 17an ZAN: 18imz LEM: 11m(a)
(c) *fabula* (Kiener, 1843) ERY: 19tma PER: 12*
(p) *listeri* (Gray, 1824) LEM: 11*-am IND: 13*-a SUM: 14asj TAS: 58v^{8} ZEA:54h QUE: 47* FIJ: 46* MEL:41* MAL: 48*-jsgv RYU: 49trs MIC: 42mpc(g) POL: 44c ×CAP: 17n

Notadusta Schilder, 1935

punctata (Linnaeus, 1771) (CAP: 17n) ZAN: 18z LEM: 11*-l (ERY: 19ta) IND: 13c SUM:14asj DAM:15*-s QUE: 47*-s FIJ: 46* MEL: 41* MAL: 48*-gv RYU: 49tr(s) MIC:42*-o
(i) *trizonata* (Sowerby, 1870) POL: 44cstmf
rabaulensis Schilder, 1964 MEL: 41b MAL: 48p
katsuae (Kuroda, 1960) MAL: 48p RYU: 49rs
martini (Schepman, 1907) QUE: 47c MAL: 48mp
superstes (Schilder, 1930) FIJ: 46h

Palmadusta Iredale, 1930

asellus (Linnaeus, 1758) ZAN: 18z LEM: 11* IND: 13c SUM: 14tasj DAM: 15* ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48*-v RYU: 49*-c MIC: 42*-o POL:44fp(hu)
clandestina (Linnaeus, 1767) CAP: 17n ZAN: 18*-sg LEM: 11* ERY: 19ta IND: 13mc SUM:14asj DAM:15*-s ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48*-sgv RYU: 49*-c MIC: 42*-o POL: 44cp(hu)
artuffeli (Jousseaume, 1876) RYU: 49*-c JAP: 37f MIC: 42o(m)
saulae (Gaskoin, 1843) SUM: 14t DAM: 15b QUE: 47* MAL: 48p (RYU: 49s) MIC: 42p [*rare, scattered*]
contaminata (Sowerby, 1832) CAP: 17n LEM: 11rs SUM: 14a DAM: 15e QUE: 47bc FIJ:46c MEL:41b MAL:48cjsgbp RYU: 49r
lutea (Gmelin, 1791) (IND:13c) SUM: 14sj DAM: 15* MEL: 41g MAL: 48*-v RYU: 49*-c
(p) *humphreysi* (Gray, 1825) ZEA: 54h QUE: 47* FIJ: 46*-h(s) MIC: 42j
ziczac (Linnaeus, 1758) CAP: 17an ZAN: 18*(-sg) LEM:11* ERY:19* PER:12oh(p) IND: 13mc SUM: 14aj(s) DAM: 15e QUE: 47*-s FIJ: 46*-s MEL: 41b(s) MAL: 48mtcp RYU: 49*-c MIC: 42mpc
diluculum (Reeve, 1845) CAP: 17n ZAN: 18imz ERY: 19a

(c) *virginalis* Schilder & Schilder, 1938 LEM: 11*-l ERY: 19a
lentiginosa (Gray, 1825) (ERY: 19a) PER: 12*(-o) IND: 13bmc

Purpuradusta Schilder, 1939

gracilis (Gaskoin, 1849) IND: 13c SUM: 14masj ZEA: 54h QUE: 47* MEL: 41b(m) MAL: 48* RYU: 49* JAP: 37f(c) MIC: 42mc(op)
(c) *irescens* (Sowerby, 1870) DAM: 15* TAS: 58f
(i) *notata* (Gill, 1858) ZAN: $18z^2$(sg) ERY: 19* PER: 12*
hammondae (Iredale, 1939) DAM: 15*-s QUE: 47*-s
(s) *raysummersi* Schilder, 1960 MAL: 48p
fimbriata (Gmelin, 1791) CAP: 17an ZAN: 18z(im) LEM: 11* (ERY: 19at) IND: 13c SUM: 14asj DAM: 15be MEL: 41g MAL: 48mtcbp RYU: 49trs MIC: 42mp
(i) *unifasciata* (Mighels, 1845) FIJ: 46fs MIC: 42j POL: 44stgfmp HAW: 43*
minoridens (Melvill, 1901) (SUM: 14a) ZEA: 54h QUE: 47* FIJ: 46* MEL: 41sb MAL: 48p RYU: 49rs MIC: 42p POL: 44*-mpj(g)
serrulifera (Schilder & Schilder, 1938) POL: 44*-j (huc)
microdon (Gray, 1828) SUM: 14j (ZEA: 54h) (QUE: 47cqt) FIJ: 46* MEL: 41sb MAL: 48mtbp(g) RYU: 49trs
(s) *chrysalis* (Kiener, 1843) ZAN: 18z LEM: 11amr ERY: 19ta

Blasicrura Iredale, 1930

quadrimaculata (Gray, 1824) SUM: 14msj DAM: 15* QUE:47cqt (FIJ:46f) MEL: 41* MAL: 48*-v RYU: 49tr MIC: 42pj(c)
luchuana (Kuroda, 1960) RYU: 49r
(s) *dayritiana* (Cate, 1963) MAL: 48p
coxeni (Cox, 1873) MEL: 41s
(m) *hesperina* Schilder & Summers, 1963 MEL: 41bmag
pallidula (Gaskoin, 1849) SUM: 14j DAM: 15* ZEA: 54h QUE: 47cqt FIJ: 46chf MEL: 41* MAL: 48*-g RYU: 49tr MIC: 42p
(c) *summersi* (Schilder, 1958) FIJ: 46fts
interrupta (Gray, 1824) IND: 13mc SUM: 14*-k MAL: 48matjp
rashleighana (Melvill, 1888) FIJ: 46c
(s) *eunota* (Taylor, 1916) HAW: 43hf × PAN: 88w
(p) *latior* (Melvill, 1888) HAW: 43*
teres (Gmelin, 1791) CAP: 17an ZAN: 18*-sg LEM: 11* IND: 13c SUM: 14*-k DAM: 15* ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48*-sgv RYU: 49*-c MIC: 42* POL: 44*-g(t) HAW: 43* × PAN: 88cp
(p) *subteres* (Weinkauff, 1881) POL: 44cstg
goodalli (Sowerby, 1832) FIJ: 46s MIC: 42ge(m) POL: 44*-j

Bistolida Cossmann, 1920

kieneri (Hidalgo, 1906) ZAN: 18imz LEM: 11* IND: 13c
(s) *depriesteri* (Schilder, 1933) SUM: 14*-k ZEA: 54h QUE: 47* FIJ: 46* MEL: 41* MAL: 48*-v RYU: 49tr(s) MIC: 42m
(i) *landeri* Schilder & Griffiths, 1962 POL: 44p
oweni (Sowerby, 1837) ZAN: 18z LEM: 11*-1
(i) *vasta* (Schilder & Schilder, 1938) CAP: 17n(a)
hirundo (Linnaeus, 1758) ZAN: 18z LEM: 11* (ERY: 19t) IND: 13mc SUM: 14* DAM: 15* ZEA: 54h QUE: 47*-s FIJ: 46* MEL: 41* MAL: 48* RYU: 49*-c MIC: 42* POL: 44huc
ursellus (Gmelin, 1791) SUM:14*-tk (DAM:15b) ZEA: 54h QUE: 47cqt FIJ: 46*(-s) MEL: 41* MAL: 48*-gv RYU: 49trs MIC: 42g(e)
erythraeensis (Sowerby, 1837) ERY: 19*
stolida (Linnaeus, 1758) CAP: 17n ZAN: 18imz LEM: 11amrs (IND: 13c) SUM: 14tsj DAM: 15be QUE: 47*-s FIJ: 46* MEL: 41* MAL: 48mjsbp RYU: 49*-c JAP: 37k MIC: 42* POL: 44hufp

Ovatipsa Iredale, 1931

chinensis (Gmelin, 1791) SUM: 14j DAM: 15*-s QUE: 47* FIJ: 46*-t MEL: 41* MAL: 48mtp RYU: 49*-c MIC: 42* POL: 44p(hu)
(i) *amiges* (Melvill & Standen, 1915) HAW: 43h

(i) *variolaria* (LAMARCK, 1810) CAP: 17an ZAN: 18*-sg LEM: 11* (ERY: 49tax)
(m) *tortirostris* (SOWERBY, 1906) CAP: 17a(n)
(p) *coloba* (MELVILL, 1888) ERY: 19a (PER: 12k) IND: 13bmc SUM: 14ma)

Cribraria JOUSSEAUME, 1884

cribraria (LINNAEUS, 1758) LEM: 11rcdl ERY: 19ta(m) IND: 13c SUM: 14*-k DAM: 15bes TAS: 58f QUE: 47*-s FIJ: 46* MEL: 41* MAL: 48*-acsv(j) RYU: 49trs MIC: 42*-o POL: hp × HAW: 43h
(c) *comma* (PERRY, 1811) CAP: 17n ZAN: *-sg LEM: 11ams ERY: 19a
cribellum (GASKOIN, 1849) LEM: 11r
esontropia (DUCLOS, 1833) LEM: 11r
catholicorum SCHILDER & SCHILDER, 1938 QUE: 47c FIJ: 46ch MEL: 41sb
gaskoini (REEVE, 1846) HAW: 43hf × MIC: 42j
cumingi (SOWERBY, 1832) FIJ: 46s MIC: 42g(ce) POL: 44*-mpj

SUMMARY

This accurate and concise method to catalogue reliable and probable localities facilitates both to map the distribution of each species and subspecies, as well as to compose lists of cowries collected or expected at any locality. The communicated data answer our present knowledge which surely will be increased by future investigations.

LITERATURE CITED

BORRADAILE, L. A.
1914. Bibliography of the marine fauna: Synopsis of the classification. 2nd. ed. London: Challenger Soc.

EKMAN, SVEN
1935. Tiergeographie des Meeres. Leipzig. 142 pp.; 242 figs.

HERTLEIN, LEO GEORGE & EDWIN C. ALLISON
1960. Species of the genus *Cypraea* from Clipperton Island. The Veliger 2 (4): 94 - 95; plt. 22 (1 April 1960)

HIDALGO, JOAQUIN GONZALES
1906. Monografía de las especies vivientes del género *Cypraea*. Mem. Acad. Cienc. Madrid, 25: 1 - 240; (1907) 241 - 588; I to XV.

INGRAM, WILLIAM MARCUS & KARL WALTON KENYON
1945. Cypraeidae of the Admiralty Islands. Nautilus 58 (4): 129 - 134

NOMURA, SHICHIHEI & KOTORA HATAI
1936. A note on the zoological provinces in the Japanese Seas. Bull. Biogeogr. Soc. Japan 6 (21): 207 - 214; plt. 13

SCHILDER, FRANZ ALFRED
1924. Systematischer Index der rezenten Cypraeidae. Arch. Naturgesch. 90 (A.4): 179 - 214; 1 diagram

1927. Revision der Cypraeacea (Moll. Gastr.). Arch. für Naturgesch. 91 (for 1925) (A. 10): 171 pp.; 1 diagram

1932. Cypraeacea. In Fossilium Catalogus I: Animalia, part 55: 276 pp.

1941. Verwandtschaft und Verbreitung der Cypraeacea. Arch. Molluskenk. 73 (2 - 3): 57 - 120; 2 plts.

1943. Zur Verwandtschaft der Litoralfaunen. Arch. Molluskenk. 75 (2-3): 68 - 82; 2 maps

1952. Einführung in die Biotaxonomie (Formenkreislehre). Jena, 162 pp.; 121 maps.

1956. Lehrbuch der allgemeinen Zoogeographie. Jena, 150 pp.; 134 maps and diagrams.

1960. Probleme der Zoogeographie. Zool. Anz. Suppl. 23: 369 - 373; 4 maps

1964. The distribution of *Erronea walkeri* SOWERBY (Cypraeidae). Hawaiian Shell News, n.ser. 49: 7 - 8; 1 map

SCHILDER, FRANZ ALFRED, & MARIA SCHILDER
1938 - 1939. Prodrome of a monograph on living Cypraeidae. Proc. Malacol. Soc. London, 23(3 - 4): 119 - 231.

1940. Die Verbreitung und Häufigkeit der rezenten Cypraeidae. Arch. Moll. 72 (2 - 3): 33 - 56

SCHOTT, GERHARD
1926. Geographie des Atlantischen Ozeans. 2nd. ed. Hamburg. 368 pp.; 28 plts.; 115 figs.

1935. Geographie des Indischen und Stillen Ozeans. Hamburg. 413 pp.; 38 plts.; 114 figs.

SPICER, VARNUM DENNIS PHILIP
1941. Shells from Midway. Nautilus 55 (1): 1 - 2

STEADMAN, W. R. & BERNARD C. COTTON
1946. A key to the classification of the cowries (Cypraeidae). Rec. So. Austral. Mus. 8: 503 - 530; 6 plts.

WHITLEY, G. P.
1937. The Middleton and Elizabeth Reefs. Austral. Zoologist 8: map on p. 199

A Proposed Reclassification of the Family Marginellidae

(Mollusca : Gastropoda)

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(9 Text figures)

This article is intended as an advance treatment of the Marginellidae in preparation for the Treatise on Invertebrate Paleontology, as was Coan (1964) for three of the families of the Rissoacea. Advance treatment is useful for three reasons. First, the references to the original descriptions may be included in the bibliography. Second, discussion can be included regarding the choices made and arrangement used. Third, the position of the west American species can be stated in terms of a world-wide look at the genera available.

Most authors reviewing the Marginellidae have included a summary of the systems of classification used by previous workers, with a list of most of the available generic names described prior to that time. Each of these major reviewers has come to much the same conclusion, that no matter which features of morphology are chosen as a basis for division, these occur in nearly every possible combination, so that the resulting classification is anything but satisfying. Nearly all of these workers have felt the necessity of adding one or more new generic names for unusual forms or for purposes of clarification.

A brief history of this sort is in order. The genus *Marginella* was named by Lamarck (1799). Kiener (1834-41) discussed the species in his set of monographs. Swainson (1840) was the first major reviewer. He used the genera *Volutella* and *Persicula* and he described *Gibberula* and *Glabella*. *Persicula* and *Hyalina* had been named by Schumacher (1817) and *Volutella* was a contribution of Swainson in 1829. Hinds (1844a) tried to simplify the situation by dividing the family into two sections, not realizing that he was adding two more genus-level names for later systematists to struggle with, *Cryptospira* and *Phaenospira*. In addition, he named *Volvarina* as a subgenus.

Sowerby's monograph in his Thesaurus was published in 1846. The next reviews of significance were those of Gray (1847), who divided the family into three groups, and of Petit (1851), who used three different groups. Herrmannsen (1852) named *Prunum*. Gray again reviewed the family in 1857, and he used three divisions of still another nature. At the same time he named *Rabicea* and *Closia*. From 1860 on, individual genera were named in various publications, and we need not mention these. Reeve's monograph in Conchologia Iconica was published in 1864-1865. In 1870, Redfield catalogued the existing species and commented on the proliferation of useless generic names. Jousseaume (1875), just five years after Redfield's comments, named six new genera in his review, making a total of thirteen divisions of the family in his work. The story continues with Weinkauff (1879, 1880), who monographed all of the known species, leaving all species in the genus *Marginella,* but the appendix to his work contains a proposed outline of classification. This outline employed shell characters that have not been used by subsequent workers. He also added the genus *Eratoidea* to the growing list of names.

Tryon (1882-1883), like Weinkauff, made no attempt to divide the listed species into genera, other than *Marginella,* but he, in contrast to Weinkauff, did subdivide the species into meaningful but unnamed categories. Sacco (1890) provided two new generic names for fossil forms.

In his review of Marginellidae, Cossmann (1899) proposed a classification using three genera, seven subgenera, and a larger number of sections. He made an effort to analyze critically, and his arrangement proved to be a useful one. He contributed two more generic names. Tomlin (1917, 1919) merely listed the genera, but he made no attempt to use them. His two papers give a complete catalogue of all known species and their synonyms. It is a most useful work for students of the family. Thiele (1929) discussed this family in his Handbuch

and he used three genera, but a still different three than any preceding author. The *Hyalina*-like forms were included in the genus *Marginella*, while he added *Marginellona* MARTENS, 1903, a strange form from the Indian Ocean, as a full genus.

The next work of importance is that of GRANT & GALE (1931). They adopted a three-part classification, using the genera *Marginella, Persicula,* and *Hyalina*. WENZ (1943) used ten genera in his review.

The situation remained stable for several years more. In 1951 HABE named three genera, *Volvarinella, Microvulina*, and *Kogomea,* for the Japanese species. He later (1960) synonymized his genus *Microvulina* with *Crithe* GOULD, 1860, a genus whose monotypic species was first illustrated by YEN (1944). WENZ (1941) had placed the form in another superfamily. Although YEN's figure is not useful, one can tell that GOULD had a marginellid in mind. In 1957 LASERON named thirty new genera. This nearly equals the total number of genera that had been published prior to that time.

BARNARD (1962) described the genus *Diluculum*. He felt that genera should be founded on a knowledge of the soft parts, and he named his new genus based on a species of which he had studied the radula and external aspects of the living animal. He states, "These names [specific names of three South African Marginellidae], however, are merely names given to shells of molluscs whose anatomy is unknown. They may be useful to shell collectors, but really they have no status as *species*, and should have no place in a fauna-list." Generic and specific names are based on real animals, and it is the task of the systematist to find out more about the characters of the hard and the soft parts of the animals of the seventy-four genera that have been named in the Marginellidae prior to 1962. HINDS (1844a) named his two new genera in order to simplify the classification of the group, which at that time consisted of six genera. MACPHERSON & GABRIEL (1962) made an effort to reconcile the many Australian names with the work of WENZ (1943).

There is a slightly stronger basis for the classification here adopted, because a little more is now known about the animals and radulae of a few species. In addition, when all the genera are studied at one time, patterns appear with regard to the distribution of the forms, both in time and geographically. Relating these various lines of evidence—geological, geographical, shell-character, radular, and that from the external morphology of the soft parts—we can draw some conclusions.

The family apparently originated in the ancient Tethys Sea. These first forms are preserved in the Eocene strata of the Paris Basin and from as far east as Australia. The family spread rapidly through the tropical seas, for some species have been found in the Oligocene of Washington State. Today, species may be found in tropical and subtropical seas throughout the world.

There seem to be three major divisions in the family. There are many relatively large species with brightly colored shells. These species are said to possess long, thin tentacles (Figures 1, 2). For discussion of the animals in

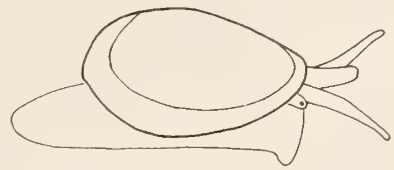

Figure 1:
Animal of *Volvarina* (*Haloginella*) *mustelina* (ANGAS, 1871), x 4.
(after LASERON, 1957, p. 290, figure 35)

Figure 2:
Animal of *Marginella* (*Austroginella*) *johnstoni* (PETTERD, 1884) x 6. (after MURRAY, 1959, p. 25, figure 2)

recent papers, useful works are COTTON (1944), BURN (1958), LASERON (1957), and MURRAY (1959). In addition, a few radulae have been figured. The radula of the Marginellidae consists of a single rachidian plate. The group of larger species, or the Marginellinae, has a flat or curved plate with many cusps (Figures 3 - 5).

The subfamily Marginellinae reaches its maximum proliferation on the west coast of Africa, where it represents an appreciable portion of the gastropod fauna. This subfamily extends to the Caribbean, where the subgenus

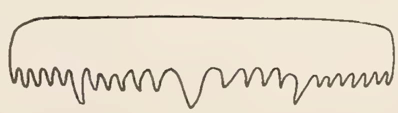

Figure 3:
Rachidian plate of *Volvarina* (*Haloginella*) *philippinarum* (REDFIELD, 1848), x 150.
(after TROSCHEL, 1867, plate 5, figure 8)

Figure 4:
Rachidian plate of *Volvarina* (*Sinuginella*) *pygmaea* (Sowerby, 1846), x 820.
(after Powell, 1932, plate 35, figure 20)

Prunum and the genera *Bullata* and *Persicula* are the predominant forms. The Marginellinae also reach the Mediterranean and spread around Africa to the Red Sea and to the Indian Ocean. Today, most of the members of this subfamily in the rich Australian fauna are small species.

It is probable that the species in the Panamic Province of west America are derived from those in the Caribbean

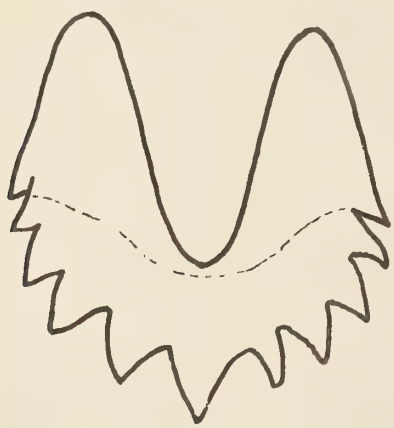

Figure 5:
Rachidian plate of *Persicula persicula* (Linnaeus, 1758) magnification unknown. (after Thiele, 1929, p. 354, figure 425)

fauna, having arrived through the Panama area when it was a connecting link between the two great seas. Nearly every west American species has a Caribbean analogue.

There is also a large number of very small species with characteristically white shells. The small species are described as having short, triangular tentacles (Figures 6, 7).

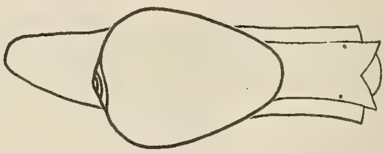

Figure 6: Animal of *Cystiscus cystiscus* (Redfield, 1870), x 6.
(after Stimpson, 1865, plate 8, figure 2d)

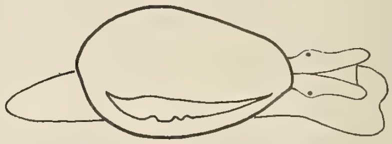

Figure 7: Animal of *Cystiscus angasi* (Crosse, 1870), x 15.
(after Laseron, 1957, p. 290, figure 34)

The rachidian plate of the group of smaller species, the Cystiscinae, is small, arched, and has fewer cusps (Figure 8). Troschel (1867) and Barnard (1959) have supplied good figures of radulae. It is unfortunate that the rules of priority force us to use the name Cystiscinae for these small species, as the type species of *Cystiscus* is poorly known, while the subfamily could be based, for instance, on the more common Mediterranean form.

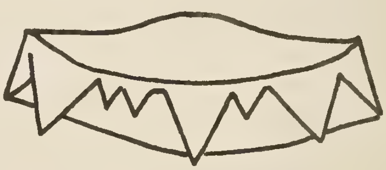

Figure 8: Rachidian plate of *Cystiscus cystiscus* (Redfield, 1870), magnification unknown. (after Stimpson, 1865, plate 8, figure 2c)

The subfamily Cystiscinae, although found throughout the world, is the dominant group in the eastern Pacific. One species, *Cypraeolina pyriformis* (Carpenter, 1865a), may be found as far north as Alaska, making that species the most northern representative of any member of the family.

The new subfamily **Marginelloninae** is here named for the genera *Marginellona* Martens (1903) and *Afrivoluta* Tomlin (1947). Although there are some pronounced differences between the shells of these two rare forms, both are relatively large and have a rachidian plate with numerous cusps (Figure 9). For further discussion con-

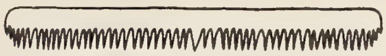

Figure 9:
Rachidian plate of *Afrivoluta pringlei* Tomlin, 1847, x 27.
(after Barnard, 1963, p. 199)

cerning *Afrivoluta* see Barnard (1963) and van Bruggen (1963), and concerning *Marginellona* see Thiele (1903).

Two taxonomic questions should be commented on. *Gibberulina* Monterosato, 1884, was named with the words "*nom. sost.*" (substitute name) for the reason that *Bullata bullata* causes tautonomy. According to ICZN Rules 18b and 67i (see Stoll, 1961), the type of Monterosato's genus must be *Voluta bullata* Born, 1778, and his genus is a junior synonym of *Bullata* Jousseaume, 1875. Subsequent use of *Gibberulina* by authors for members of the Cystiscinae is, therefore, incorrect.

Hyalina Schumacher, 1817, remains problematical. Schumacher's monotype is *H. pellucida* Schumacher, 1817. Dodge (1955) gives substantial reason to believe that this species is *Voluta pallida* Linnaeus, 1767, and that *Voluta pallida* is a recognizable Caribbean species. Therefore, *Hyalina* is a prior name of *Neovolvaria* Fischer, 1883.

I suggest the following outline of classification for west American species:

Marginellinae

Marginella Lamarck, 1799

(Prunum) Herrmannsen, 1852

M. albuminosa Dall, 1919
M. curta Sowerby, 1832
M. sapotilla Hinds, 1844a
= *M. evax* Li, 1930
M. woodbridgei Hertlein & Strong, 1951

Persicula Schumacher, 1817

P. adamsiana Pilsbry & Lowe, 1932
P. dubiosa Dall, 1871
P. frumentum (Sowerby, 1832) [*Marginella*]
P. hilli (Smith, 1950) [*Marginella*]
P. imbricata (Hinds, 1844a) [*Marginella*]
P. maculosa (Kiener, 1834) [*Marginella*]
P. phrygia (Sowerby, 1846) [*Marginella*]
P. porcellana (Gmelin, 1791) [*Voluta*]
=*P. tessellata* (Lamarck, 1822) [*Marginella*]

Volvarina Hinds, 1844a

(Haloginella) Laseron, 1957

V. californica (Tomlin, 1916) [*Marginella*]
= *V. parallela* (Dall, 1918) [*Marginella*]
V. myrmecoon (Dall, 1919) [*Hyalina*]
V. rosa (Schwengel, 1938) [*Marginella*]
V. taeniolata Mörch, 1860

Cystiscinae

Cystiscus Stimpson, 1865

C. jewettii (Carpenter, 1857b in Gould & Carpenter) [*Marginella*]
= *C. nanella* (T. S. Oldroyd, 1925) [*Marginella*]
C. minor (C. B. Adams, 1852) [*Marginella*]
C. polita (Carpenter, 1857a) [*Marginella*]
C. politula (Dall, 1910, *ex* Cooper MS) [*Marginella*]
C. regularis (Carpenter, 1865b) [*Marginella*]

Cypraeolina Cerulli-Irelli, 1911

C. margaritula (Carpenter, 1857a) [*Marginella*]
= (?)*C. pyriformis* (Carpenter, 1865a) [*Volutella*]

Kogomea Habe, 1951

K. subtrigona (Carpenter, 1865b) [*Marginella*]
= (?) *K. oldroydae* (Jordan, 1926) [*Marginella*]
K. morchii (Redfield, 1870) [*Marginella*], *nom. nov.*
= *K. coniformis* (Mörch, 1860) [*Gibberula*], *non Marginella coniformis* Sowerby, 1850

genus uncertain

Marginella anticlea Dall, 1919
Marginella eremus Dall, 1919

References are in the bibliography for all of these species. I hope to review the Eastern Pacific species at a later date, figuring some of the yet unfigured type specimens. It is probable that the arrangement used in that review will differ significantly from this.

CONVENTIONS and ABBREVIATIONS

The conventions and abbreviations used here are, for the most part, those used in the Treatise on Invertebrate Paleontology (see Moore, 1960).

The asterisk and square brackets set off the name of the type species; the type of designation is then indicated by the abbreviations given below.

The date and letter (if present) indicate the work where the associated taxon was named or subsequent designation made. The numbers following the date refer to the place in the work where the name or subsequent designation appears. These words are listed in the bibliography in the case of genera, their homonyms, or subsequent designations. The interested student may consult the works of TOMLIN (1917 and 1919) for references to species.

If the author of a species is not given, it is to be assumed that the species was first described by the author of the associated genus and in the same work. The type species are listed as they were designated, originally, or subsequently, with the exception that abbreviations are filled out and the authors of the species have been added.

Abbreviations are as follows:

? (before a name)	- position questioned
? (after =)	- synonymy questioned
=	- synonym
auctt. (auctores)	- of authors
emend.	- emendation
ex	- from
ICZN	- International Commission of Zoological Nomenclature (see STOLL, 1961)
in synon.	- generic name proposed in the synonymy of another
inv.	- invalid
M	- type fixed by monotypy
MS	- manuscript of
nom. correct. (nomen correctum)	- name with an intentionally altered spelling of the sort allowed under the ICZN rules
nom. nov. (nomen novum)	- new name
nom. nud. (nomen nudum)	- a name which, as originally published, fails to meet the requirements of the ICZN rules, and has no status in nomenclature.
nom. transl. (nomen translatum)	- name derived by valid emendation of a previously published name as the result of transfer from one taxonomic category to another within the "family-level."
non	- not of
OD	- type fixed by original designation
SD	- type fixed by subsequent designation
sp. err.	- spelling error
T	- type fixed by tautonomy

ACKNOWLEDGMENTS

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MARGINELLIDAE FLEMING, 1828: 328,
nom. correct., H. & A. ADAMS, 1853: 188,
ex Marginelladae
[= Marginellaceae HINDS, 1844b]

Marginellinae FLEMING, 1828,
nom. transl., SWAINSON, 1840: 98

Marginella LAMARCK, 1799: 70 [**Voluta glabella* LINNAEUS, 1758; M]

= *Marginellana* H. & A. ADAMS, 1853: 189, sp. err.
= *Marginellarius* FRÖRIEP in DUMÉRIL, 1806: 338, inv. emend.
= *Marginellus* MONTFORT, 1810: 558, inv. emend.
= *Marginilla* SWAINSON, 1831: (2) 2, 87, sp. err.
= *Porcellana* GRAY, 1847: 142, *non* LAMARCK, 1801: 153 [**Voluta glabella* LINNAEUS, 1758; OD]
= *Cucumis* DESHAYES, 1830: 35 (in synon.)
= *Pseudomarginella* MALTZAN, 1880: 108 [**P. adansoni* = *Voluta glabella* LINNAEUS, 1758; M] (see COOK [1922])
= *Pterygia, auctt., non* RÖDING, 1798: 51
= *Stazzania* SACCO, 1890: 318 [**Marginella emarginata* SISMONDA, 1847, *ex* BONELLI MS; M]
= *Stazziana* COSSMANN, 1919: 68, sp. err.

(Marginella)

(Alaginella) LASERON, 1957: 286 [**Marginella ochracea* ANGAS, 1871; OD]

(Austroginella) LASERON, 1957: 285 [**Marginella muscaria* LAMARCK, 1822; OD]

(Carinaginella) LASERON, 1957: 286 [**Marginella carinata* SMITH, 1891; OD]

(Denticuloglabella) SACCO, 1890: 317 [**Marginella deshayesi* MICHELOTTI, 1847; M]

(Euryentome) COSSMANN, 1899: 95 [**Marginella crassilabra* CONRAD, 1833, *non* BORY DE ST. VINCENT, 1827 = *Marginella silabra* PALMER, 1937, *nom. nov.;* OD]

(Gibberula) SWAINSON, 1840: 323 [**G. zonata* = *Volvaria oryza* LAMARCK, 1822 = (?) *Voluta miliaria* LINNAEUS, 1758; M]

= *Gibbernia, auctt.,* sp. err.
= *Giberula* SOWERBY, 1842: 153, sp. err.
= *Gibrerula* JOUSSEAUME, 1884: 177, sp. err.
= *Eratoidea* WEINKAUFF, 1879: 140 [**Marginella margarita* KIENER, 1834; SD Cossmann, 1899:87]

(Mioginella) LASERON, 1957: 287 [**Marginella regula* COTTON, 1949; OD]

(Protoginella) LASERON, 1957: 285 [**Marginella lavigata* BRAZIER, 1877 = *M. laevigata, emend.,* HEDLEY, 1901, *non* EICHWALD, 1830 = (?) *M. valida* WATSON, 1886; OD]

(Prunum) HERRMANSEN, 1852: 113 [**Voluta prunum* GMELIN, 1791; M]

= *Egouena* JOUSSEAUME, 1875: 192 [**E. egouen* = *Marginella amygdala* KIENER, 1841; SD TOMLIN, 1917: 244] (ICZN Rule 32b. First reviser is NEAVE, 1939: 2: 199)
= *Eguoena* JOUSSEAUME, 1875: 167, sp. err.
= *Egouana* JOUSSEAUME, 1875: 207, sp. err.
= *Egociena* COTTON, 1949: 199, sp. err.

= *Leptegouana* WOODRING, 1928: 237 [**Voluta guttata* DILLWYN, 1817, *ex* SOLANDER MS, *non* LINK, 1807 = *Marginella longivaricosa* LAMARCK, 1822; OD]
= *Septegouana, auctt.,* sp. err.

= *Porcellanella* CONRAD, 1863: 564, *nom. nud.* [**P. bella, nom. nud.;* M], *non* WHITE in MACGILLIVRAY, 1852, 2: 394
= *Porcellana* COSSMAN, 1899: 92, sp. err., *non* LAMARCK, 1801: 153, *non* GRAY, 1847: 142

(Simplicoglabella) SACCO, 1890: 313 [**Marginella taurinensis* MICHELOTTI, 1847; SD EAMES, 1952:119]

(Stromboginella) LASERON, 1957: 289 [**Marginella crassidens* CHAPMAN & CRESPIN, 1928; OD]

Balanetta JOUSSEAUME, 1875: 168 & 269 [**B. baylii;* M]

(Balanetta)

(Ovaginella) LASERON, 1957: 280 [**Marginella ovulum* SOWERBY, 1847; OD]

Bullata JOUSSEAUME, 1875: 167 & 250 [**B. bullata* (BORN, 1778) = *Voluta bullata* BORN, 1778; T]

= *Gibberulina* MONTEROSATO, 1884: 139, inv. emend. (as "*nom. sost.*")

= *Volutella* SWAINSON, 1829: (2) 1: *Marginella* pl. 1, *non* PERRY, 1810: pl. 2, no. 1 [**Marginella bullata* LAMARCK, 1822 = *Voluta bullata* BORN, 1778; OD]

(Bullata)

(Closia) GRAY, 1857:36 [**C. sarda* (KIENER, 1834) = *Marginella sarda* KIENER, 1834; M]

(Cryptospira) HINDS, 1844a: 76 [*C. tricincta* = *Marginella tricincta* HINDS, 1844a; SD GRAY, 1849: 142]
= *Crystospira* COTTON, 1949: 199, sp. err.

Canalispira JOUSSEAUME, 1875: 168 & 270 [**C. olivellaeformis;* M]

Cassoginella LASERON, 1957: 287 [**Marginella palla* COTTON, 1949; OD]

Dentimargo COSSMANN, 1899: 90 [**Marginella dentifera* LAMARCK, 1803; OD]

Glabella SWAINSON, 1840: 133 & 324 [*"P." *faba* = *Voluta faba* LINNAEUS, 1758; SD GRAY, 1847: 142]

= *Glabrella, auctt.,* sp. err.

= *Faba* FISCHER, 1883: 602 [**Marginella faba* (LINNAEUS, 1758) = *Voluta faba* LINNAEUS, 1758; M]

= *Phaenospira* HINDS, 1844a: 72 [**P. "noduta"* = *Marginella nodata* HINDS, 1844; SD GRAY, 1847: 142]
= *Phoenospira* PETIT, 1851: 40, sp. err.

Hiwia MARWICK, 1931: 129 [**Marginella (H.) amplificata;* OD]

Hyalina SCHUMACHER, 1817: 234 [**H. pellucida* =(?) *Voluta pallida* LINNAEUS, 1767; M]

= *Neovolvaria* FISCHER, 1883: 602 [**Marginella pallida* (LINNAEUS, 1767) = *Voluta pallida* LINNAEUS, 1767; M]

Mesoginella LASERON, 1957: 282 [**Marginella turbinata* SOWERBY, 1846; OD]

(Mesoginella)

(*Plicaginella*) LASERON, 1957: 285 [**Marginella formicula* LAMARCK, 1822; OD]

(*Spiroginella*) LASERON, 1957: 283 [**Marginella leia* COTTON, 1944; OD]

(*Urniginella*) LASERON, 1957: 287 [**Marginella cassidiformis* TATE, 1878; OD]

Microspira CONRAD, 1868 [*"*P.*" (*M.*) *oviformis* = *Volutella* (*M.*) *oviformis* CONRAD, 1868; M]

Persicula SCHUMACHER, 1817: 235 [**P. variabilis* = *Voluta persicula* LINNAEUS, 1758; M]

= *Persigula* AYRES, 1916: 107, sp. err.
= *Persicola* SWAINSON, 1840: 323, sp. err.
= *Rabicea* GRAY, 1857: 37 [**Persicula interrupta* (LAMARCK, 1822) = *Marginella interrupta* LAMARCK, 1822 = *Voluta interruptolineata* MEGERLE, 1816; M]

Serrata JOUSSEAUME, 1875: 167 & 230 [**S. serrata* (GASKOIN, 1899) = *Marginella serrata* GASKOIN, 1849; T]

(*Serrata*)

(*Baroginella*) LASERON, 1957: 286 [**B. infirma;* OD]

(*Conuginella*) LASERON, 1957: 288 [**Marginella inermis* TATE, 1878; OD]

(*Dentiginella*) LASERON, 1957: 288 [**Marginella metula* COTTON, 1949; OD]

(*Exiginella*) LASERON, 1957: 289 [**Marginella winteri* TATE, 1878; OD]

(*Hydroginella*) LASERON, 1957: 284 [**H. dispersa;* OD]

(*Vetaginella*) LASERON, 1957: 288 [**Marginella doma* COTTON, 1949; OD]

Volvarina HINDS, 1844 a: 75 [**Marginella nitida* = *Voluta mitrella* RISSO, 1826; SD REDFIELD, 1870: 221]

= *Volvaria* JOUSSEAUME, 1875: 219, sp. err., *non* LAMARCK, 1801: 93
= *Volvorina* JOUSSEAUME, 1875: 225, sp. err.

(*Volvarina*)

(*Diluculum*) BARNARD, 1962: 14 [**D. inopinatum;* OD]

(*Halogmella*) LASERON, 1957: 284 [**Marginella mustelina* (ANGAS, 1871) = *Hyalina mustelina* ANGAS, 1871; OD]

= *Pillarginella* GABRIEL, 1962: 197 [**Marginella columnaria* HEDLEY & MAY, 1908; OD]

(*Neptoginella*) LASERON, 1957: 283 [**N. fascicula;* OD]

(*Phyloginella*) LASERON, 1957: 280 [**P. compressa;* OD]

(*Sinuginella*) LASERON, 1957: 282 [**Marginella inconspicua* SOWERBY, 1846; OD]

Volvarinella HABE, 1951: 101 [**V. makiyamai;* OD]

= *Longinella* LASERON, 1957: 286, *non* GROS & LESTAGE, 1927: 161 [**Marginella maugeana* HEDLEY, 1915; OD]

Cystiscinae STIMPSON, 1865: 55,
nom. transl., COAN, herein, *ex* Cystiscidae

Cystiscus STIMPSON, 1865: 55 [**C. capensis, non Marginella capensis* KRAUSS, 1848, *ex* DUNKER MS = *Marginella cystiscus* REDFIELD, 1870 (*nom. nov.*); M]

= *Cysticus, auctt.*, sp. err.
= *Euliginella* LASERON, 1957: 282 [**Marginella angasi* CROSSE, 1870, *ex* BRAZIER MS; OD]

Crithe GOULD, 1860: 384 [**C. atomaria*; M]
= *Microvulina* HABE, 1951: 105 [**M. nipponica;* OD]

(*Crithe*)

(*Epiginella*) LASERON, 1957: 279 [**E. ablita*; OD]

Cypraeolina CERULLI-IRELLI, 1911: 231 [**Cryptospira* (*Cypraeolina*) *clandestina* (BROCCHI, 1814) = *Voluta clandestina* BROCCHI, 1814; M]

= *Cypreolina* PALLARY, 1912: 189, sp. err.
= *Merovia* DALL, 1921: 86 [**M. pyriformis* (CARPENTER, 1865) = *Volutella pyriformis* CARPENTER, 1865 = (?) *Marginella margaritula* CARPENTER, 1857; M]
= *Mervia* COTTON, 1949: 198, sp. err.
= *Microginella* LASERON, 1957: 280 [**Marginella anxia* HEDLEY, 1909; OD]

Deviginella LASERON, 1957: 283 [**Marginella brachia* WATSON, 1886; OD]

Extra JOUSSEAUME, 1894: 98 & 101 [**E. extra*; M]

Granula JOUSSEAUME, 1875: 167 & 246 [**G. bensoni* (REEVE, 1865) = *Marginella bensoni* REEVE, 1865; SD herein]

Granulina JOUSSEAUME, 1888 [**G. pygmaea* (ISSEL, 1869) = *Marginella pygmaea* ISSEL, 1869, *non* SOWERBY, 1846 = *Marginella isseli* G. & H. NEVILL, 1875 *(nom. nov.)*; M]

Hianoginella LASERON, 1957: 288 [**Marginella physa* COTTON, 1949; OD]

Kogomea HABE, 1951: 103 [**Marginella novemprovincialis* (YOKOYAMA, 1928) = *Erato novemprovincialis* YOKOYAMA, 1928; OD]

(Kogomea)

(Lataginella) LASERON, 1957: 288 [**Marginella kitsoni* CHAPMAN, 1921; OD]

Marginellopsis BAVAY, 1911: 241 [**M. serrei;* M]

Nudifaba EAMES, 1952: 122 [**Marginella (N.) rakhiensis;* OD]

?*Topaginella* LASERON, 1957: 288 [**Marginella octoplicata* TENISON-WOODS, 1877; OD]

Triginella LASERON, 1957: 280 [**Marginella malina* HEDLEY, 1915; OD]

Marginelloninae COAN, *subfam. nov.*

Marginellona MARTENS, 1903: 108 [**M. gigas;* M] = *Marginelloma* COSSMANN, 1906: 225, sp. err.

Afrivoluta TOMLIN, 1947: 244 [**A. pringlei*; OD]

LITERATURE CITED

ADAMS, HENRY, & ARTHUR ADAMS

1853-1858. The genera of Recent Mollusca, arranged according to their organization. London; 1: vi-xl, 1-484; 2: 1-661; 3: plts. 1-138.
(Marginellidae - 1: 188 - 195, October 1853)

ADAMS, CHARLES BAKER

1852. Catalogue of shells collected at Panama, with notes on synonymy, station, and habitat. Ann. and Lyceum Nat. Hist. New York 5: 229 - 344 (June); 345 - 548 (July)

AYRES, BERNARDO

1916. Catálogo das conchas exóticas existentes no Museu Zoológico da Universidade de Coímbra. 1: 1 - 386 Coímbra. Portugal.

BARNARD, KEPPEL HARCOURT

1959. Contributions to the knowledge of South African marine Mollusca, Part II :Gastropoda: Prosobranchiata: Rhachiglossa Ann. South Afric. Mus. 45 (1): 1 - 237: 52 figs. (June

1962. A new genus in the family Marginellidae. Proc Malacol. Soc. London 35 (1): 14 - 15; 1 fig. (April)

1963. The family position of *Afrivoluta pringlei* TOMLIN. Journ. Conch. 25 (5): 198 - 199; 1 fig. (October)

BAVAY, ARTHUR

1911. Une marginellidée nouvelle de Cuba. Bull. Mus. Nation. Hist. Nat., Paris 17: 240 - 243; 1 fig.

BRUGGEN, A. C. VAN

1963. A re-examination of the types of Recent Mollusca of the Port Elizabeth Museum. Ann. Cape Provinc. Mus. 3: 75 - 81; 6 figs.

BURN, ROBERT

1958. Molluscan field notes, Part I. Victorian Naturalist 75: 97 - 99 (October)

CARPENTER, PHILIP PEARSALL

1857 a [1855 - 1857]. Catalogue of the collection of Mazatlan shells in the British Museum collected by Frederick Reigen. London; xvi + 552 pp. [July 1855 - June 1857, each part dated at foot of first page].

1857 b. see: GOULD, A. A. & —

1865 a. Diagnoses des mollusques nouveau provenant de Californie et faisant partie du Musée de l'Institution Smithsonienne. Journ. de Conchyl. (3) 5 [13]: 129 - 149. (April 1865)

1865 b. Diagnoses of new forms of Mollusca, collected by Col. Jewett. Ann. Mag. Nat. Hist. (3) 15: 394 - 399 (May 1865) (section containing Marginellidae).

CERULLI-IRELLI, SERAFINO

1911. Fauna malacologica marina, Part 5. Paleontogr. Ital., Mem. di Paleontol. 17: 227 - 275; plts. 21 - 26
(Marginellidae: 231 - 233)

COAN, EUGENE

1964. A proposed revision of the rissoacean families Rissoidae, Rissoinidae, and Cingulopsidae. The Veliger 6 (3): 164 to 171; 1 text fig. (1 January 1964)

CONRAD, TIMOTHY ABBOTT

1863. Catalogue of the Miocene shells of the Atlantic slope. Proc. Acad. Nat. Sci. Philadelphia for 1862. 14: 559 - 583.

1868. Descriptions of Miocene shells of the Atlantic slope. Amer. Journ. Conch. 4 (2): 64 - 68: 2 plts. (October 1868)

COOKE, ALFRED HANDS

1922. On the pseudo-genus *Pseudomarginella*, v. Maltzan. Proc. Malacol. Soc. London 15 (1): 3 - 5 (April 1922)

COSSMANN, ALEXANDRE ÉDOUARD MAURICE

1899. Essais de paléoconchologie comparée 3: 1 - 201; 8 plts.
(Marginellidae: 79 - 99)

1906. Essais de paléoconchologie comparée 7: 1 - 261; 14 plts.

1919. Supplément aux mollusques éocéniques de la Loire-inférieure. Bull. Soc. Sci. Nat. l'Ouest France (3) 5: 53 to 141; 4 plts.

COTTON, BERNARD CHARLES

1944. Australian margin shells: Marginellidae. So. Austral. Natural. 22 (4): 9 - 16; 1 plt. (30 November 1944)

1949. Australian Recent and Tertiary Mollusca, family Marginellidae. Rec. So. Austral. Mus. 9 (4): 197 - 224; plts. 17 to 20

Dall, William Healey

1871. Descriptions of sixty new forms of mollusks from the west coast of North America and the north Pacific Ocean, with notes on others already described. Amer. Journ. Conch. 7 (2): 93 - 160; plts. 13 - 16 (2 November 1871)

1918. Descriptions of new species of shells, chiefly from Magdalena Bay, Lower California. Proc. Biol. Soc. Washington 31: 5 - 8 (27 February 1918)

1919. Descriptions of new species of Mollusca from the North Pacific Ocean in the collection of the United States National Museum. Proc. U. S. Nat. Mus. 56 (2295): 293 - 371 (30 August 1919)

1921. Summary of the marine shellbearing mollusks of the northwest coast of America, from San Diego, California, to the Polar Sea. . . . Bull. U. S. Nat. Mus. 112: 1 - 217; plts. 1 - 22 (24 February 1921)

Deshayes, Gérard Paul

1830. Histoire naturelle des vers. 2: 1 - 144. Paris

Dodge, Henry

1955. A historical review of the mollusks of Linnaeus, Part 3: The genera *Bulla* and *Voluta* of the class Gastropoda. Bull. Amer. Mus. Nat. Hist. 107 (1): 1 - 158 (7 November 1955)

Duméril, C. see Fröriep, 1806

Eames, Frank Evelyn

1952. A contribution to the study of the Eocene in Western Pakistan and western India. C. The description of the Scaphopoda and Gastropoda from standard sections in the Rakhi Nala and Zinda Pir areas of the Western Punjab and in the Kohad District. Phil. Trans. Roy. Soc. London (B) 236: 1 - 168; 6 plts. (2 January 1952)

Fischer, Paul Henri

1883. Manuel de conchyliologie et de paléontologie conchyliologique ou histoire naturelle des mollusques vivantes et fossiles 2 (6): 513 - 608. Paris (20 December 1883) (Marginellidae: 602 - 604)

Fleming, John

1828. A history of British animals, exhibiting the descriptive characters and systematical arrangement of the genera and species of quadrupeds, birds, reptiles, fishes, Mollusca, and Radiata of the United Kingdom. Edinburg and London.

Fröriep, L. F.

1806. C. Duméril's Analytische Zoologie. Weimar.

Gabriel, Charles J.

1962. Additions to the marine molluscan fauna of south eastern Australia including descriptions of new genus *Pilarginella*, six new species and two subspecies. Mem. Nation. Mus. Melbourne, no. 25: 177 - 210; 1 plt. (1 May 1962)

Gmelin, J. F.

1791. Systema naturae per regna tria naturae. Editio decima tertia, aucta, reformata, 1 (6): 3021 - 3910. Leipzig.

Gould, Augustus Addison

1860. Descriptions of shells collected in the North Pacific Exploring Expedition under Captains Ringold and Rogers. One part: Proc. Boston Soc. Nat. Hist. 7: 382 - 385 (Decemb.)

Gould, Augustus Addison & Philip Pearsall Carpenter

1857. Descriptions of shells from the Gulf of California and the Pacific coasts of Mexico and California, part 2. Proc. Zool. Soc. London for 1856: 198 - 208 (7 January 1857)

Grant, Ulysses S., IV & Hoyt Rodney Gale

1931. Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions. Mem. San Diego Soc. Nat. Hist. 1: 1 - 1036; 15 figs.; plts. 1 - 32 (3 November 1931) (Marginellidae: 628 - 633)

Gray, John Edward

1847. A list of the genera of Recent Mollusca, their synonyma and types. Proc. Zool. Soc. London 15 (178): 129 - 219 (10 November 1847)

1857. Guide to the systematic distribution of Mollusca in the British Museum. Part I: xii + 230 pp. London.

Gros, A. J. & J. M. Lestage

1927. Contribution à l'étude des larves des Ephéméroptères. Series 4: Le group Euthyplocien. Ann. Biol. Lacust. Brussels 15: 119 - 162; 20 figs.

Habe, Tadashige

1951. Illustrated catalogue of Japanese shells, edited by Dr. Tokubei Kuroda. 16: Marginellidae and Hydrocenidae in Japan: 101 - 107; 12 figs. (10 December 1951)

1960. Notes on the species of Japanese shells described by A. A. Gould. Venus 21 (1): 10 - 31 (July 1960)

Herrmannsen, August Nicolaus

1852. Indicis generum malacozoorum supplementa et corrigenda. Kassel, London, Paris. v + 140 pp.

Hertlein, Leo George & Archibald McClure Strong

1951. Descriptions of three new species of marine gastropods from West Mexico and Guatemala. Bull. So. Calif. Acad. Sci. 50 (2): 76 - 80 (May/August 1951)

Hinds, Richard Brinsley

1844 a. Descriptions of Marginellae collected during the voyage of H. M. S. Sulphur, and from the collections of Mr. Cuming. Proc. Zool. Soc. London 7: 72 - 77 (September 1844)

1844 b. The zoology of the voyage of H. M. S. Sulphur, under the command of Captain Sir Edward Belcher . . . during 1836 - 1842, 2(Mollusca) (2): 25 - 48; plts. 8 - 14 London (October 1844)

Jordan, Eric Knight

1926. Molluscan fauna of the Pleistocene of San Quintin Bay, Lower California. (Expedition to Guadalupe Island, Mexico, in 1922 — No. 4) Proc. Calif. Acad. Sci. 15 (7): 241 - 255; 1 fig.; plt. 25 (26 April 1926)

Jousseaume, Felix P.

1875. Coquilles de la famille des marginelles. Rev. Mag. Zool. (3) 3: 164 - 271; plts. 7 - 8

1884. Descriptions des mollusques nouveaux. Bull. Soc. Zool. France **9**: 169 - 192; plts.

1888. Descriptions des mollusques receuillis par M. le Dr. Faurot dans la Mer Rouge et le Golfe d'Aden. Mém. Soc. Zool. France **1** (2): 165 - 223 (October 1888)

1894. Diagnoses des coquilles de nouveaux mollusques. Bull. Soc. Phil. Paris (8) **6**: 98 - 105

Kiener, Louis Charles [continued by P. Fischer after 1873]

1834 - 1841. Spécies général et iconographie des coquilles vivantes: genre marginelle (livr. 1 - 6: 1 - 30 - December, 22, 1834; livr. 59 - 71: 31 - 44 - 1841)

Lamarck, Jean-Baptiste Pierre Antoine de Monet de

1799. Prodrome d'une nouvelle classification des coquilles. Mém. Soc. Hist. Nat. Paris **1**: 63 - 91

1801. Système des animaux sans vertèbres, ou tableau général des classes, des ordres, et des genres de ces animaux; . . . .: viii + 432 pp. Paris

1822. Histoire naturelle des animaux sans vertèbres. **7**: 711 pp. Paris

Laseron, Charles F.

1957. A new classification of the Australian Marginellidae (Mollusca), with a review of species from the Solanderian and Dampierian zoogeographical provinces. Austral. Journ. Marine and Freshwater Res. **8** (3): 274 - 311; 84 figs.

Li, Chih Chang

1930. The Miocene and Recent Mollusca of Panama Bay. Bull. Geol. Soc. China **9**: 249 - 296; plts. 1 - 8 (October 1930)

Macgillivray, John

1852. Narrative of the voyage of H. M. S. Rattlesnake, commanded by the late Captain Owen Stanley, . . . during the years 1846 - 1850. London, 2 vols. [Appendix 4 in **2**: Descriptions of some apparently new species of Annulosa, (collected by Mr. Macgillivray during the voyage of H. M. S. Rattlesnake), by Adam White; 387 - 395; 1 plt.]

Macpherson, J. Hope & Charles J. Gabriel

1962. Marine mollusks of Victoria. Melbourne Univ. Press, xv + 475 pp.

Maltzan-Federow, Hermann von

1880. Eine neue Molluskengattung. Nachrichtsblatt der Deutsch. Malakozool. Gesellsch. **12**: 106 - 109 (Nov./Dec.)

Martens, Eduard [Carl] von

1903. Die beschalten Gastropoden der deutschen Tiefsee-Expedition 1898 - 1899. A: Systematisch-geographischer Teil: 1 - 146; plts. 1 - 5; 1 fig.

Marwick, John

1931. The Tertiary Mollusca of the Gisborne District. Paleont. Bull. New Zealand Geol. Surv., No. 13: iii + 177 pp.; 17 plts.

Mörch, Otto Andreas Lowson

1860. Beiträge zur Molluskenfauna Central-Amerikas. Malak. Blätter **7**: 66 - 96 (July 1860); 97 - 106 (Aug. 1860)

Monterosato, Tommaso di Maria Alleri di

1884. Nomenclatura generica e specifica di alcune cochiglie mediterranea: 152 pp. Palermo (after August 1884)

Montfort, Denys de

1810. Conchyliologie systématique et classification méthodique des coquilles. Paris, 2 vols. (Marginellidae in vol. 2)

Moore, Raymond Cecil (editor and director)

1960. Treatise on invertebrate paleontology. Part I (Mollusca 1): xiii + 351 pp.; figs. 1 - 216

Murray, Florence V.

1959. The animal of *Austroginella johnsoni* (Petterd). Journ. Malacol. Soc. Austral. **3**: 23 - 25; 2 figs.

Neave, Sheffield Airey

1939 - 1940. Nomenclator zoologicus. Zool. Soc. London, 4 vols.

Oldroyd, Thomas Shaw

1925. The fossils of the Lower San Pedro fauna of the Nob Hill Cut, San Pedro, California. Proc. U. S. Nat. Mus. **65** (22) [No. 2535]: 1 - 36; 2 plts. (16 January 1925)

Pallary, Paul

1912. Catalogue des mollusques du littoral méditerranéen de l'Égypte. Mém. Inst. Égypt. **7** (3): 69 - 205; 4 plts.

Perry, George

1810 - 1811. Arcana or the museum of natural history: containing the most recent discovered objects. London [Plate 1 was issued in 1810]

Petit de la Saussaye, S.

1851. Notice sur le genre marginelle, *Marginella*, Lamarck, suivi d'un catalogue synonymique des éspèces de ce genre. Journ. de Conchyl. **2**: 38 - 59; part of plts. 1 and 2

Pilsbry, Henry Augustus & Herbert N. Lowe

1932. West Mexican and Central American mollusks collected by H. N. Lowe 1929-31. Proc. Acad. Nat. Sci. Philadelphia **84**: 33 - 144; 6 figs.; plts. 1 - 17; 2 photographs (21 May 1932)

Powell, Arthur William Baden

1932. The Recent Marginellidae of New Zealand, with descriptions of some new species. Trans. New Zealand Instit. **62**: 203 - 214; plts. 33 - 36 (31 March 1932)

Redfield, John H.

1870. Catalogue and synonymy of the genera, species and varieties of Recent Mollusca, described prior to January 1st, 1867. Part 5: Marginellidae. Amer. Journ. Conch. **6** (2): 215 - 269 (6 October 1870)

Reeve, Lovell Augustus

1864 - 1865. Conchologia iconica: or, illustrations of molluscous animals, **15**: Monograph of the genus *Marginella*. plts. 2 - 13 (August 1864) and plts. 1 and 14 - 27, Index & Erratum (January 1865)

Röding, Peter Friederich

1798. Museum Boltenianum, pars secunda contiens conchylia: viii + 199 pp. Hamburg.

SACCO, FREDERICO

1890. I molluschi dei terreni terziarii del Piedmonte e della Ligura descritti da Luigi Bellardi. Part 6 (Volutidae, Marginellidae, Columbellidae). Mem. R. Acad. Sci. Torino (2) 40: 295 - 368; plts. 1 - 2

SCHUMACHER, CRETIEN FRÉDÉRIC

1817. Essai d'un nouveau système des habitations des vers testacés. Copenhagen, iv + 287 pp.; 22 plts.

SCHWENGEL, JEANNE S.

1938. Zoological results of the George Vanderbilt South Pacific Expedition, 1937. Part I, — Galapagos Mollusca. Proc. Acad. Nat. Sci., Philadelphia 90: 1 - 3; 3 figs. (13 May 1938)

SMITH, MAXWELL

1950. New Mexican and Panamic shells. Nautilus 64 (2): 60 - 61; plt. 4 (27 October 1950)

SOWERBY, GEORGE BRETTINGHAM (first of name)

1832. Characters of new species of Mollusca and Conchifera collected by Mr. Cuming. Proc. Zool. Soc. London for 1832: 50 - 61 (5 June 1832), 104 - 108 (31 July 1832)

SOWERBY, GEORGE BRETTINGHAM (second of name)

1842. A conchological manual. Ed. 2; London

1846. Thesaurus conchyliorum, or figures and descriptions of Recent shells. 1 (7): 341 - 406 (Marginellidae: 373 - 406; plts. 74 - 78)

STIMPSON, WILLIAM

1865. On certain genera and families of zoophagous gastropods. Amer. Journ. Conch. 1 (1): 55 - 64; plts. 8 - 9 (25 February 1865)

STOLL, NORMAN RUDOLPH *et al.*

1961. International code of zoological nomenclature adopted by the XV International Congress of Zoology. London xviii + 176 pp.

SWAINSON, WILLIAM

1820 - 1833. Zoological illustrations or original figures and descriptions of new, rare, or interesting animals, selected chiefly from the classes of ornithology, entomology, and conchology, and arranged according to their natural affinities. London, 6 vols. [series 1: 1 - 3; series 2: 1 - 3]

1840. A treatise on malacology, or the natural classification of shells and shellfish. London, pp. 1 - 419; text figs. (Marginellidae: 323 - 324 in part 2)

THIELE, JOHANNES

1903. Die geschalten Gastropoden der deutschen Tiefsee-Expedition 1898 - 1899. B: Anatomisch-systematische Untersuchungen einiger Gastropoden: 149 - 174; plts. 6 - 9

1929. Handbuch der systematischen Weichtierkunde. (Jena, Gustav Fischer, 1929 - 1935); 1154 pp.; 893 text figs. (Marginellidae: 353 - 356)

TOMLIN, JOHN READ LE BROCKTON

1916. Note on the *Marginella varia* of Sowerby. Nautilus 29 (12): 138 - 139 (April 1916)

1917. A systematic list of the Marginellidae. Proc. Malacol. Soc. London 12 (5): 242 - 306 (22 August 1917)

1919. A systematic list of the fossil Marginellidae. Proc. Malacol. Soc. London 13 (3): 41 - 65 (16 April 1919)

1947. A new South African volutid. Journ. Conch. 22 (10): 244 - 245; 1 fig.

TROSCHEL, FRANZ HERMANN

1867. Das Gebiss der Schnecken zur Begründung einer natürlichen Classification. 2 (2): 49 - 96; plts. 5 - 8 (Dec.) (Marginellidae: 57 - 60; plt. 5)

TRYON, GEORGE WASHINGTON, JR.

1882-1883. Manual of conchology; structural and systematic, (1) 5 (17): 1 - 64 (December 21, 1882); (1) 5 (20): 193 to 276 (18 October 1883)
(Marginellidae: (17): 5 - 58; plts. 2 - 13; (20): 197 - 255)

WEINKAUFF, HEINRICH CONRAD

1879. Systematisches Conchylien-Cabinet von Martini und Chemnitz: die Gattungen *Marginella* und *Erato*. Nürnberg 141 pp. and plts.

1880. Catalog der Arten der Gattung *Marginella* Lam. Jahrb. Deutsch. Malakozool. Gesellsch. 1880: 40 - 64

WENZ, WILHELM

1941. Handbuch der Paläozoologie 5: 961 - 1200. Berlin. (October 1941)

1943. Handbuch der Paläozoologie 6: 1201 - 1506. Berlin. (Marginellidae: 1372 - 1380) (October 1943)

WOODRING, WENDELL PHILLIPS

1928. Miocene mollusks from Bowden, Jamaica. Part 2: Gastropods and discussion of results. Carnegie Inst. Washington, Publ. 385: vii + 564 pp.; 3 figs.; plts. 1 - 40 (28 Nov. 1928) (Marginellidae: 236 - 242)

YEN, TENG-CHIEN

1944. Notes on some unfigured type-specimens of Chinese mollusks from the North Pacific Expedition. Proc. Calif. Acad. Sci., (4) 38: 561 - 586; plts. 50 - 51 (22 August 1944)

Burrowing Limitations in Pelecypoda

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(4 Text figures)

INTRODUCTION

STUDENTS OF LAMELLIBRANCHS have given attention to their several modes of locomotion.

Some clams creep or crawl through sand and mud *(Trachycardium quadragenarium* CONRAD, 1837); others swim *(Pecten irradians* CONRAD, 1837); most burrow downward *(Tresus nuttalli* (CONRAD, 1837) or *Panope generosa* GOULD, 1850), leaving only the tip of the siphon to protrude above the surface. Observations on the burrowing of clams have been made by MACGINITIE & MACGINITIE (1949, pp. 80-81, 329, 352), GUTSELL (1930, pp. 569-625), BORRADAILE *et al.* (1961, pp. 622-635), RICKETTS & CALVIN (1952, pp. 196-197, 268-305), and BUCHSBAUM (1955, pp. 188-198). However, no one has established the existence of a mechanism whereby clams, once in position and covered with sand, could elevate themselves back toward the surface. This I intend to do in this paper.

As one attempts to understand how lamellibranchs might maintain themselves at certain depths in the medium in which they are buried, certain hypotheses may be drawn regarding beneath-the-sand locomotion: (1) there is no movement in the burrow but rather adjustment to water-sand level through action of the siphon alone; (2) upward movement of the clam in the burrow may be achieved by such means as (a) rapid extension of the foot "downward," resulting in an "upward" pushing movement, (b) continual digging in an arc, thus placing the clam near the surface or (c) shell action, perhaps coordinated with foot action, involving filling the mantle cavity then ejecting water forcibly, resulting in elevation; and (3) the clam may elevate through the effect of buoyancy, the clam being less dense than the medium in which it lives. These hypotheses are based upon illustrations, references, and discussions of clam locomotion and under-the-sand position found in the above listed references plus those of Pohlo (1963, pp. 98-103) (1964, pp. 321-330), FITCH (1950, pp. 285-311), LIGHT *et al.* (1954 pp. 219-238), FRASER & SMITH (1928, pp. 249-268), FRASER (1930, pp. 569-626), WEYMOUTH (1920, pp. 29-63) and observations of the writer.

MATERIAL AND OBSERVATIONS

Ten species of clams were selected for this study, and results are based upon observations of these. The species studied were (1) *Macoma nasuta* (CONRAD, 1837), (2) *Macoma secta* (CONRAD, 1860), (3) *Protothaca staminea* (CONRAD, 1837), (4) *Saxidomus nuttalli* CONRAD, 1837, (5) *Mya arenaria* LINNAEUS, 1758, (6) *Tresus nuttalli* (CONRAD, 1837), all studied in field experiments at Drakes Estero, Marin County, and Bodega Bay, Sonoma County, California, (7) *Tivela stultorum* (MAWE, 1823), Pismo Beach, California, (8) *Panope generosa* GOULD, 1850, Puget Sound, Washington, (9) *Siliqua patula* (DIXON, 1788), Copalis Beach, Washington, and (10) *Chione californiensis* (BRODERIP, 1835), two specimens of which were obtained alive from Baja California but were not observed under field conditions. All clams did not respond identically.

To test the hypotheses outlined above, clams were dug up and then reburied in aquaria, five gallon cans, or in the sand in open clam beds.

It was soon evident that the conditions inside an aquarium or can are quite different from those in the open clam bed with natural wave action. Temperature, water action, water oxygenation, and the proportion of solid media suspended in water are all factors which are very difficult to duplicate when trying to reconstruct the natural environment for the clam inside the aquaria or cans. No clams planted in aquaria or five gallon cans showed any ability to elevate.

All clams in this study extended their siphon tip to or very near to the surface of the sand for exchange of water (LIGHT et al. 1954, p. 232). In normal posture the posterior end bearing the siphon is nearer the surface; the

[1] This study was part of a thesis for the Master of Arts Degree in Biology at San Francisco State College.

ventro-anterior end with the extensible foot points downward. The clams used appeared to be in normal posture when near a 90° vertical angle, regardless of the depth or age of the clam; *Macoma* was a partial exception, being inclined nearly 30-60° with the incurrent siphon making a soft bend to reach the surface. All clams studied have an extensible downward-pointing foot. It serves as a probe, anchor, and contractor during digging.

In downward digging, generally speaking, the clam extends the foot and simultaneously changes the foot shape into a thin, blade-like projection, the tip inserting into the sand if digging from on top the sand, or probing deeper into the sand if already buried. The sinuses fill with blood, the body of the foot enlarges and may exceed the shell diameter, and then the foot contracts, drawing the shell into or through the sand. Under the sand this movement is accompanied by spurts of water through the excurrent siphon.

Digging action below the sand can be seen in part by using aquaria, and in all clams so examined the over-all foot action was similar, but degree of extension, frequency of contractions, and intensity of contraction differed markedly in different species. In no case was any action seen or felt which might suggest the clam could reverse this mechanism and push upwardly.

EXPERIMENTS AND RESULTS

Replanting and Depth Experiments: To check a clam's ability to move upward or show directional movement other than downward, clams were dug and replanted in a series of planting experiments at various depths in open clam beds, in aquaria, and in five-gallon cans. The aquaria and cans were then planted at different depths in the clam bed. Controls of two types were used in all cases: (1) clams of about the same size were marked in the bed and left untouched; (2) other clams were dug up, reburied at the same depth and marked. This allowed size, age, and natural depth comparisons between experimental clams and controls. Stakes were used for marking in all cases.

Of the species used in this study, 25 were planted at depths less than extended siphon length plus two to four inches, all 25 clams lived and within one week each established its burrow. In all experiments where the clam was planted in excess of extended siphon length plus about seven inches, they all perished within seven days.

Of 25 *Protothaca staminea* planted in excess of three to four inches deep, 18 were dead within a week and the seven remaining were dead at one month. Twenty-five planted at extended siphon length plus two inches remained alive. Critical depth for this species is about two inches. *Tivela stultorum*, when planted at approximately 18 inches, reestablished at normal depth within 48 hours if planted within bounds of active surf. Normal depth for *Tivela* is 2-6 inches, fully extended siphon approximately 4-6 inches. Plantings on the beach above the region of wave action showed the clams did not change position. Using 20 *Siliqua patula*, a similar experiment showed the clam regaining normal depth by the next low tide from an 18 to 24 inch burial. Normal depth for *Siliqua* is 2-10 inches, with fully extended siphons 6-9 inches. The above measurements are of mature clams with shell length of approximately 6 inches. As in the experiments with *Tivela, Siliqua* also failed to show any movement when planted in moist sand above the level of wave action.

A single *Panope generosa* was planted at six inches below extended siphon depth, and when checked in one month was found alive. It had created a six-inch-deep conical depression in the surface layer of sand, and the siphon tip emerged from the lowest point. The clam had not elevated.

Additional Cover Experiments: Using *Tresus nuttalli* and *Protothaca staminea,* a variation of the planting experiment was devised. Four-sided wooden frames with sides from four to twelve inches high were built (see diagram, figure 1). These were then placed around undisturbed clams in various regions of the beds. The frames were anchored in place and filled with sand. Sixteen *T. nuttalli* covered with approximately four inches or more of sand were all dead at the end of three weeks, while 16 covered with approximately two to three inches of sand

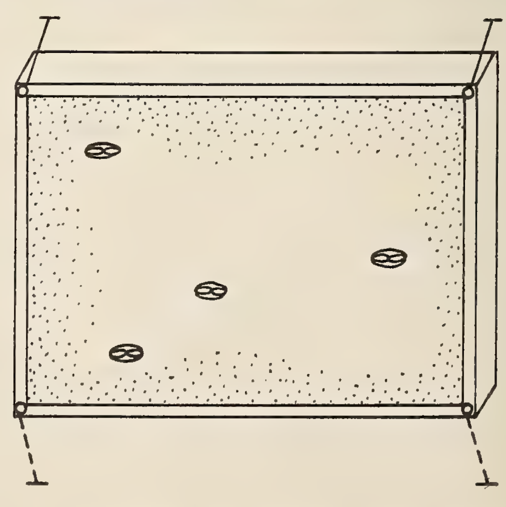


Figure 1: Wooden frame in position for adding environmental sand to clams, where siphons are at surface level.
(Surface view looking down onto the clam bed)
[the size of the frames varied, depending upon the species involved; for *Protothaca staminea* the frames were 4 feet by 4 feet, while for *Tresus nuttalli* they were 6 feet by 8 feet]

were alive at the end of three weeks. Ten *P. staminea* covered with one inch of sand remained alive while 14 having three inches of additional cover had perished in the same length of time.

As a final check to determine a clam's ability to move upward, *Tresus nuttalli* with enlarged concave burrow openings were selected. Ten selected burrows were measured and marked; the depressions were then filled gently with sand. The ten clams occupying burrows with depressions about two inches deep were alive with the burrow depressions partly reformed at the end of two weeks. Ten clams in depressions four or more inches deep were dead (see diagram, figure 2).

In any of these cases one might conclude that if the clam could have elevated rather than perish, it would have done so.

Clams used for the experiments with reburial, additional cover, and burrow depression filling appeared unable to move upward and adjust to these modifications of the environment. They did show some ability in siphon extension of about one to four inches and thereby remained alive.

Posture and Reorientation Experiments: In order to determine directional movement other than downward, a series of posture experiments was devised and executed using 15 *Tresus nuttalli,* 10 *Protothaca staminea,* 10 *Tivela stultorum,* and 25 *Siliqua patula* in each experiment. The clams were immediately replanted at the depths at which they were located. Posture variations in the experiments involved (1) a 180° reversal of the clam, siphon straight down, foot up; (2) a 135° inclination, siphon down; (3) 90° inclination of three types: (a) mantle edge up, (b) mantle edge down, and (c) mantle edge to the side; and (4) a 45° inclination with the siphons up (see diagram, figure 3). Results of these experiments show that two species, *Tresus nuttalli* and *P. staminea,* could not reorient and survive in any position except the 45° inclination. Twelve *Tivela stultorum* and 24 *S. patula* repostured in the 45° inclination within 24 hours. In no case could the species used reestablish themselves from a complete reversal (all 51 specimens died); 90° inclination (all 50 specimens died); mantle edge up (all 50 specimens died); or 135° inclination, siphon down (all 50 specimens died).

Relative Density and Water Action: The clams studied have no known method of self-elevation by voluntary means, yet some elevate in the field. It is therefore strongly suggested that they may be elevated by water action. Ten species of clams were subjected to quantitative analysis in their individual densities in relation to the density of their immediate environment. The data from this work show that each clam is less dense than its environment (see Table No. 1: Table of Comparative Density). This evidence led to the hypothesis that relative density resulting in a positive buoyancy will, under prescribed conditions, elevate a clam in its burrow. This suggests that clams must dig down to establish themselves within the sand at depths appropriate to their anatomy, that depth in general in dictated by the siphon length, and that clam buoyancy causes any elevation that occurs. In either case the problem of the clam is to dig downward only. My experiments show that they cannot actively,

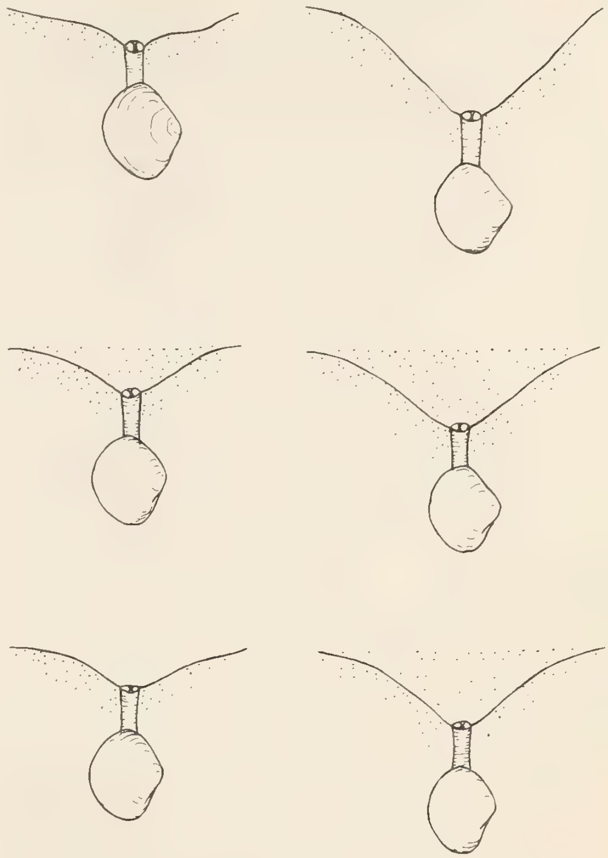


Figure 2: Addition of sand covering to concave burrows. Natural burrow depressions are marked and filled flush with sand. The depth of these burrows ranged from about one to six inches and the diameter from about two to ten inches.
Natural burrow depressions
Covered
After three weeks

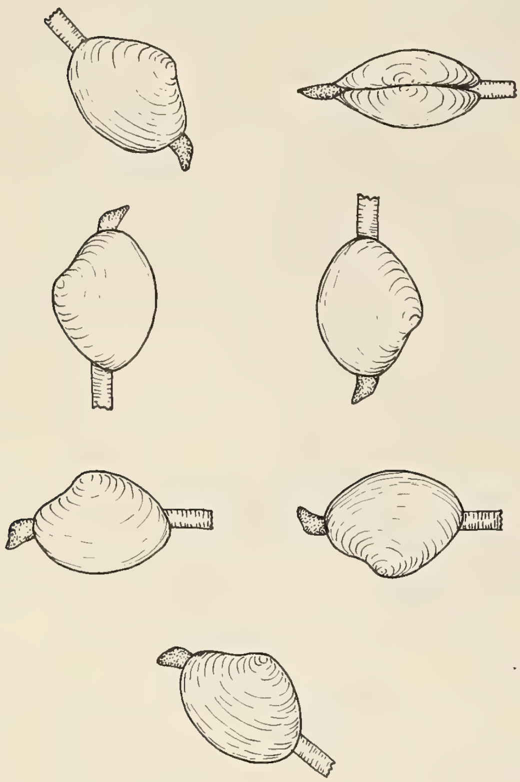


Figure 3: Diagram of posture studies
(illustrating the general procedure used in this study)
a - 45° inclination b - 90°, flat c - 180°, reversed
d - control(s), natural depth and posture for each species used
e - 90° inclination, mantle edge down f - 90°, mantle edge up
g - 135° (reverse) inclination

voluntarily elevate even when not to do so causes them to perish.

Effect of Water Action on Clam Buoyancy Inside an Aquarium: To check the effect of density on the buoyancy and digging of clams, the following experiment was conducted. Clams of different species and sizes were placed at the bottom of an aquarium (see diagram, figure 4). The aquarium was placed on a log and filled with water. Varying amounts of sand were added and the aquarium

Table 1

Table of Comparative Density
of
Clams and Sand

Base Reference = Density of sand at 3.00 gm/cc as an average of ten observations.

Panope generosa	1.38
Mya arenaria	1.31
Tivela stultorum	1.83
Tresus nuttalli	1.27
Saxidomus nuttalli	1.47
Siliqua patula	1.14
Chione californiensis	1.71
Macoma nasuta	1.21
Macoma secta	1.24
Protothaca staminea	2.04

was then rocked. If the difference in buoyancy between clam and medium were similar to that in nature, and the buoyancy hypothesis correct, the clams would be buoyed up. In all cases this did occur.

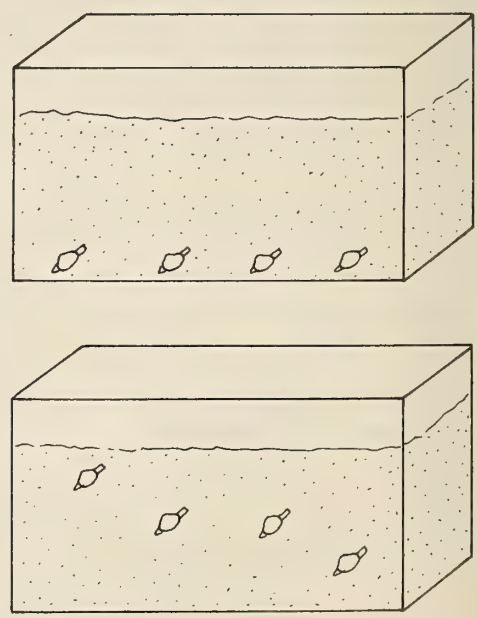


Figure 4: Demonstration of effect of buoyancy under controlled experimental conditions.
[figures indicate density in gm/cc]
a - living clams, sand, water and aquarium at start of experiment
b - same aquarium after rocking 30 tilts per minute for 10 minutes
1 — *Macoma secta* 2 — *Protothaca staminea*
3 — *Tresus nuttalli* 4 — *Tivela stultorum*

The density of the clam as compared to the environment determines the relative buoyancy and appears to be the basis for variation in the clam's digging ability and related activity. For example, *Tivela* and *Siliqua* represent clams which can move upward in the field. They live in an environment of rapid, severe, and forceful interaction of water, sand and clam. They are constantly affected by the difference in relative density which serves to buoy them upward through the sand. They maintain correct depth and position by digging downward. Conversely, *Tresus* and *Panope* live in areas of calm, slow-moving waters and are not affected by such an interaction of water, sand and self. Burrow construction, depth, burrowing ability and anatomical differences of species used clearly demonstrate adaptation to sand-buoyancy.

Burrowing and Geographical Orientation: General observations on a clam's position in the sand, which I found interesting but which were not resolved in this study, concern the geographical direction of some clams. It has been noted (Weymouth, 1920) that certain clams, e.g. *Siliqua patula* and *Tivela stultorum,* are always found in a given position or direction relative to the wave front. This fact was confirmed during this study. The apparent reason for such directional orientation is the action of the wave front on the clam. It is suggested that regardless of the geographical direction of the wave front these types of clams would show this definite orientation on the beach, and East and West are used for convenience in these remarks, because both *T. stultorum* and *S. patula* were so oriented in the beaches studied. Those two species of clams are found with the hinge and excurrent siphon facing the ocean (west), and the mantle edge and incurrent siphon facing the land (east). In rechecking these observations (Weymouth, 1923), 50 *T. stultorum* were carefully dug at Oceana, California, and in each case they were in the sand as indicated above. Ten individual *T. stultorum* were placed in an aquarium and observed as they dug into the sand. East-west orientation was not observed as they covered themselves. The orientations of well over 200 *S. patula* were observed (Fraser, 1930). In this case one needs only to walk along the ocean side of a sand spit in about one to two inches of water and observe the exposed siphon tips to see the position. In every case each clam of over 200 observed was in an east-west orientation. Twenty-four *S. patula,* with shell lengths of two to four inches, were placed in about six inches of water in a lagoon adjacent to the spit and observed as they dug back in. No directional orientation was noted. Ten clams of similar size were then placed on the ocean side of the same spit so that they were partially covered by wave action. The waves did not move or dislodge the clam and hit the clams when each wave was almost completely spent, resulting in a gentle flushing action over the clam. The clams buried in from 20 to 60 seconds, the smallest burying the most rapidly. It appeared that those clams most severely affected by wave action would be positioned by the action of the in-coming wave so that the foot was oceanward (west), and the siphon landward (east), when the wave was spent. Then as the wave withdrew the clam made a few quick initial thrusts with the foot in the soft sand and was in a diagonal position, partially buried by the time the next wave struck it. This resulted in the clam's beginning to dig back in with partial east-west orientation. However, by the time the clam was buried it was not completely east-west oriented. Two very small clams with shell size of one-half inch dug back completely within two wave actions, in 15-20 seconds, and although each began to dig while on the side, with hinge north and mantle south, they were east-west oriented by the time they had buried. From these limited observations it is suggested that clams that bury rapidly and that are affected by waves and surf (such as *Siliqua patula)* would be affected thusly: the wave has more force when incoming than retreating; as the hinge side of the clam is narrowed and offers less water resistance than the wider and rougher mantle edge, the clam is turned like a weather vane as the incoming wave hits it. Then the more gentle retreating wave flushing back over it assists the clam in obtaining an upright digging posture because of the resistance against the rough mantle edge and shell edges. It is again hit by the next wave and as it continues to dig would be swung around to the observed east-west position by the time it buries. The same clams when placed in a quiet lagoon burrowed, but no east-west position was noted.

Tivela stultorum and *Siliqua patula* were the only two species of clams in this study living in heavy surf beaches, subjected to intense wave action during each tidal change. It is my opinion that wave action is the reason for their east-west orientation. Fifty *Panope generosa* and 50 *Tresus nutalli* were observed in Puget Sound, near Olympia, Washington, and no orientation was evident. The clams appeared to be buried completely at random even though they were affected by gentle water action because of incoming and outgoing tides. The method of observation of these two species at the site was merely to walk along, observe the siphon tips and note the direction of each. In this area the species can be distinguished without digging because, when adult (four to six years), *Tresus nuttalli* frequently has barnacles on the cornified part of the siphon tip, while *Panope* was never observed with them. The reason for this was not apparent and I have not found an explanation in the literature.

Well over 500 *Tresus nuttalli* have been observed in Limatur Inlet, adjacent to Drakes Estero, Marin County, and only random positions have been noted. Two hundred

Saxidomus nuttalli were observed in Bolinas Bay. The clams checked did not show any pattern in position, including those closest to the channel. Of 200 burrows checked, in six cases two clams shared the same burrow. The clams of this species are found at about 14 to 18 inches in depth, and, because the burrows are large enough at this site, one can determine orientation by reaching into the burrows.

Judging only from these limited observations it is most probable that wave action coupled with the anatomical differences in the two edges of the clam account for an east-west orientation while the species living in more quiet waters bury in a random pattern.

SUMMARY

Experiments with ten species of clams revealed that they did not voluntarily elevate in their burrows or show directional movement other than rotational and downward.

(1) Clams replanted four to seven inches or more in excess of extended siphon length died, unless they were affected by heavy surf. If clams normally found in the beds are covered by additional sand they will perish unless they can extend the siphon through the new cover to the surface, or form a sand-free cone-shaped depression by which they have access to the surface. If the clams studied have their burrows destroyed, but the clam itself is not moved, a new burrow will be formed, provided the clam is completely covered by water for a period of time following burrow destruction.

(2) Clams living in beds subject to severe surf action can regain normal posture if they are placed in abnormal positions involving something less than a complete reversal with siphons down, a position from which no clam in this study recovered. Clams living in very calm waters cannot regain normal posture, although some do continue to live by bending their siphons to reach the surface.

(3) All clams used in this study were found to be less dense than the medium in which each species lives. If placed in aquaria and agitated along with sand and water all were buoyed upward.

This study suggests that those clams which dig downward, and continue digging downward as environmental conditions may dictate, cannot move upward without the buoyancy produced by differences in relative density and the action of the water.

Tivela stultorum and *Siliqua patula* showed definite orientation, with the hinge seaward and mantle edge shoreward. The other species studied showed no directional position in the sand. Limited observation suggests that this is due to the active and forceful effect of water in the form of waves and surf on the former two species of clams.

ACKNOWLEDGMENTS

The author wishes to thank Dr. Jack T. Tomlinson for guidance, discussion and direction in resolving many facets of this study, and Dr. Joseph G. Hall and Mr. Henry C. Scott for comments and criticisms.

LITERATURE CITED

Borradaile, L. A., F. A. Potts, L. E. Eastham, J. T. Saunders & G. A Kerkut

1961. The invertebrata. 4th ed. Cambridge Univ. Press. London; xvii + 820 pp.; 523 figs.

Buchsbaum, Ralph

1955. Animals without backbones. 4th ed. Univ. Chicago Press. xii + 405 pp. illust.

Fitch, John E.

1950. The Pismo clam. Calif. Fish and Game 36 (4): 285 - 311

Fraser, McLean C.

1930. The razor clam, *Siliqua patula* of Graham Island. Roy. Soc. Canad. Proc. and Trans., Ser. 3, 24 ( ): 141 - 154

Fraser, McLean C. & Gertrude M. Smith

1928. Notes on the ecology of the little neck clam. Roy. Soc. Canad. Proc. and Trans., Ser. 3, 22 (5): 249 - 268

Gutsell, J. S.

1930. Natural history of the ray scallop, *Pecten irradians.* U. S. Bur. Fish. Bull. 46: 569 - 626

Light, Sol Felty *et al.*

1961. Intertidal invertebrates of the central California coast. Univ. Calif. Press, Berkeley; xiv + 446 pp.; 138 figs.

MacGinitie, George, & Nettie MacGinitie

1949. Natural history of marine animals. 473 pp.; illus. McGraw-Hill, New York.

Pohlo, Ross H.

1963. Morphology and mode of burrowing in *Siliqua patula* and *Solen rosaceus.* The Veliger 6 (2): 98 - 104; figs. 1 to 6 (1 October 1963)

1964. Ontogenetic changes of form and mode of life in *Tresus nuttalli.* Malacologia 1 (3): 321 - 330; figs. 1 - 6

Weymouth, Frank W.

1920. The edible clams, mussels and scallops of California. Calif. Fish & Game Bull. 4: 77 pp.

1923. Life history and growth of the Pismo clam. Bur. Marine Fish., Fish and Game Comm., Fish Bull. 7

Growth of Three Species of *Acmaea*

BY

PETER W. FRANK

Department of Biology, University of Oregon, Eugene

(1 Text figure)

In conjunction with a more general investigation of *Acmaea digitalis* Eschscholtz, 1833 (Frank, 1965), we have observed changes in shell length of a considerable number of individually marked limpets belonging to several species. Specifically the data reported here are from 668 *A. digitalis*, 140 *A. paradigitalis* Fritchman, 1960 and 16 *A. pelta* Eschscholtz, 1833, measured in June 1963 and again in June 1964. Maximum shell length was determined to the nearest tenth millimeter using vernier calipers.

The animals are from a single rock inside Coos Bay, Oregon. However, since this rock exhibits a considerable moisture and insolation gradient, the data probably approximate average growth for these species in this region. Certainly the species differences they reveal are general. Unfortunately the animals can not be separated by sex. There are indications that, in *Acmaea digitalis* at least, any difference in growth rate of the sexes must be very small.

Table 1 presents the data for the two species for which this can be done as a size-specific frequency distribution. It is evident that *Acmaea digitalis* of all sizes grow faster than do *A. paradigitalis.* It may be of some interest that this latter species (Fritchman, 1960) was first distinguished by us from *A. digitalis* by its slower growth rate as well as its smoother shell. For both species absolute growth of the shell decreases with size in a non-linear manner. Although variability is quite great, the data show enough precision in their means to permit critical examination of various theories of mollusk growth (e. g. von Bertalanffy, 1957).

From the table and from the data on *Acmaea pelta,* Figure 1 has been constructed by graphic integration. It is intended primarily to furnish a visual index to the relative growth of the three species. The curve is least precise for *A. pelta,* and is not particularly useful as a means of determining age of shells for the other species either.

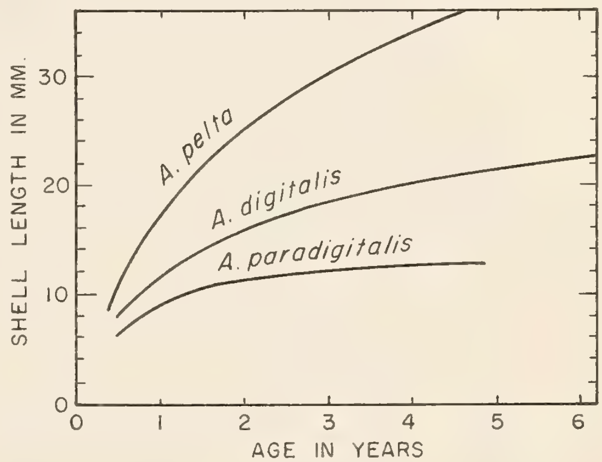


Figure 1: Average size as a function of age for three species of intertidal limpets (1963 - 1964, Central Oregon Coast)

This is because of the large standard deviations illustrated in the table. Moreover, since we are unable to identify or mark very small limpets, the early portions of the growth curves are largely conjectural. No implications regarding longevity should be drawn from the curves. From our observations, *A. digitalis* occasionally reaches 6 years and *A. paradigitalis* 4 years of age.

ACKNOWLEDGMENTS

This research was aided by a grant from the National Science Foundation (GB-977). A number of undergraduate and graduate assistants helped gather data.

Table 1

Annual change in shell length of *Acmaea digitalis* and *Acmaea paradigitalis*

	A. digitalis			*A. paradigitalis*		
IL mm	MC mm	N	SD	MC mm	N	SD
8.0				2.83	4	0.77
8.5	6.78	5	1.24	2.32	9	1.05
9.0	6.95	15	0.94	2.42	26	1.46
9.5	6.23	29	1.65	2.64	19	1.57
10.0	6.16	50	1.21	1.86	28	0.78
10.5	5.74	52	1.35	1.81	22	1.11
11.0	5.69	62	1.05	1.08	13	0.45
11.5	5.36	58	1.40	0.79	7	0.47
12.0	5.24	42	1.22	0.60	5	0.72
12.5	4.47	26	1.38	0.59	7	0.71
13.0	5.12	26	0.93			
13.5	3.89	17	1.27			
14.0	3.99	10	1.28			
14.5	3.73	25	1.26			
15.0	2.97	27	0.77			
15.5	2.56	16	0.65			
16.0	2.62	27	1.24			
16.5	2.21	21	1.15			
17.0	2.62	20	0.91			
17.5	2.37	14	0.89			
18.0	2.13	21	0.71			
18.5	1.67	20	1.16			
19.0	1.63	18	1.43			
19.5	2.14	10	0.97			
20.0	1.27	12	0.94			
20.5	1.90	12	1.23			
21.0	1.14	8	0.98			
21.5	1.57	3	0.74			
22.0	1.26	5	1.09			
22.5	1.14	9	0.89			
23.0	0.55	2	0.24			
23.5	0.90	3	0.73			
24.0	0.50	3	0.78			

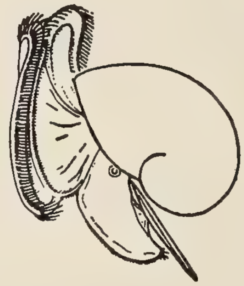
IL = initial length; MC = mean change; N = number
SD = standard deviation

LITERATURE CITED

Bertalanffy, Ludwig von
1957. Quantitative laws in metabolism and growth. Quart. Rev. Biol. 32: 217 - 231

Frank, Peter W.
1965. The biodemography of an intertidal snail population. Ecology 46: in press

Fritchman, Harry K., II
1960. *Acmaea paradigitalis,* sp. nov. (Acmaeidae, Gastropoda) The Veliger 2 (3): 53 - 57; plts. 9 - 12 (1 January 1960)



NOTES & NEWS

A. M. U.

Pacific Division

Members of the *Pacific Division* of the American Malacological Union, gathered at Asilomar during late June for their 1964 Annual Meeting, elected officers for the following year:

EDWIN C. ALLISON, *Chairman*
ALAN J. KOHN, *Vice-Chairman*
BARBARA J. GOOD, *Secretary*
FAY H. WOLFSON, *Treasurer*

All of these new officers, except Dr. Kohn, reside in the San Diego area. Ned Allison teaches geology and paleontology at San Diego State College. Alan Kohn, a member of the Department of Zoology at the University of Washington is widely known for his studies of living mollusks, particularly his biologic and taxonomic investigations of the Conidae. Barbara Good has continued to to be one of the San Diego Shell Club's most consistent and enthusiastic supporters. Fay Wolfson, a past president of the San Diego Shell Club, is occupied as a teaching assistant and graduate student of the San Diego State College's Zoology Department.

A beautiful San Diego site bordering the Pacific Ocean will be the setting for the 1965 AMU-PD Annual Meeting. That will be the Campus of California Western University which is located on the west side of Point Loma. The meeting will convene June 24 and end on June 27. Information concerning campus accommodations, prices, and meeting plans will be published at a later time. Those who are not members of the AMU but who wish to be notified individually as final arrangements are prepared may send their names and addresses with 50 cents to the Secretary, Mrs. Barbara Good, 3142 Larga Court, San Diego, California 92110.

U. M. E.

The Unitas Malacologica Europaea will hold its second European Malacological Congress in Copenhagen (Denmark) from August 10 in the morning until August 11, 1965, in the evening. Details for the program of the Congress, to be held at the Zoological Institut and Museum of the University, may be obtained from Dr. G. Høpner Petersen, % Zoologisk Museum, 5. Afdeling Universitetsparken 15, Copenhagen, Denmark. All malacologists are invited to attend.

BOOKS, PERIODICALS, PAMPHLETS

On the Hawaiian scallops of the genus *Pecten* Muller (Pelecypoda)

by C. A. FLEMING. Pacific Science, Volume 16, Number 2, pages 181 - 185, figures 1 - 4; April 1962.

The author of this paper earlier (1957) discussed the relationships of the species of pectens in the Pacific which have convex right and concave or flat left valves. That study revealed that relationships of species in a family may be obscured by differentiating very small groups into genera and subgenera.

The present paper deals principally with two species described from the Hawaiian Islands by Dall, Bartsch and Rehder. *Pecten waikikius* is placed as a subspecies of *P. jacobaeus* LINNAEUS, a species living in the Mediterranean, and *P. diomedeus* is placed questionably as a subspecies of *P. benedictus* LAMARCK which was originally described from strata of Pliocene age in France.

LGH

Shallow-Water Marine Climates and Molluscan Provinces

by CLARENCE A. HALL, Jr. Ecology, Volume 45, No. 2, pages 226 to 234, 6 figures.

I have been asked by the editor of The Veliger to comment on this paper, and must confess that I had not considered it a significant enough communication to warrant such notice. However, in reading it over, I have become aware of a peculiar manner of quotation that deserves comment. On page 227 HALL states "An animal that lives in a marine environment with a particular winter minimum sea-surface temperature in one area may live in a wholly different winter temperature in another geographic region. HEDGPETH (1957, p. 373) states: '. . . we are . . . dealing with reproductive stenotherms requiring not some minimum or maximum mean, but a narrower range . . . . This range must also be of some minimum duration — that is, the required temperature for reproduction . . . . .' "

This is quoted from a discussion of the "longitudinal discontinuity of certain species". The complete statement from which HALL has selected his excerpts reads as follows: "Although the data are as yet incomplete, enough are available to suggest that we are here dealing with reproductive stenotherms requiring not some minimum or maximum mean, but a narrower range within the extremes (as suggested by HUTCHINS' Type 1). This range must also be of some minimum duration — that is, the required temperature for reproduction is quanti-

tative as well as qualitative — and the duration of the temperature must also be taken into consideration. If an organism requires two successive months of a given mean temperature range for reproduction, it can not, of course, reproduce in an otherwise favorable region where the two months may be separated by periods of higher or lower temperatures."

It appears that HALL has missed the point of this argument, which has nothing to do with dissimilar winter temperatures as such but with similar means in geographically separated localities during the breeding season. Indeed, regions with similar winter but different summer temperatures could be involved. HALL does conclude that "The critical factor that probably determines the limits of marine shallow-water climates [*sic* — he means biogeographic regions] is the number of consecutive days or months that shallow sea water is at temperatures required for reproduction and early growth." This may be true for some species, but no data are submitted to substantiate this conclusion as a universal generalization.

In all, this paper is a review of previous papers and adds nothing new to the literature of biogeography.

JWH

THE VELIGER is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable. In the unlikely event that space considerations make limitations necessary, papers dealing with mollusks from the Pacific region will be given priority. However, in this case the term "Pacific region" is to be most liberally interpreted.

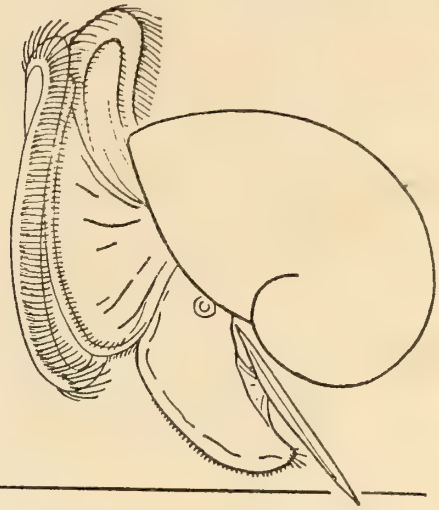
It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or lesser taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, will be published in the column "NOTES & NEWS"; in this column will also appear notices of meetings of the American Malacological Union, as well as news items which are deemed of interest to our subscribers in general. Articles on "METHODS & TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

Manuscripts should be typed in final form on a high grade white paper, 8½″ by 11″, double spaced and accompanied by a carbon copy.

THE VELIGER



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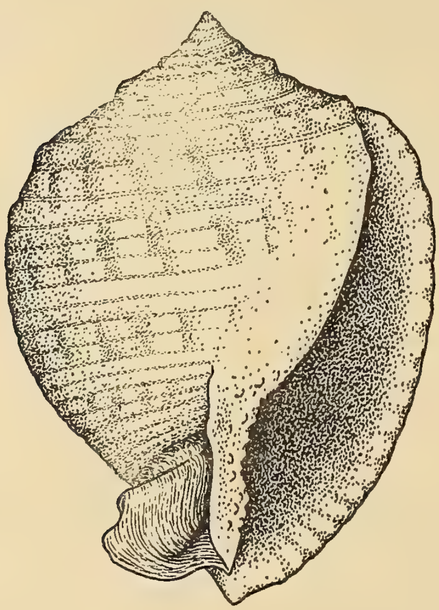


Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION, Subdivision,** SECTION,

SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).

New Taxa

The Color Pattern of *Hermissenda crassicornis* (Eschscholtz, 1831)

(Gastropoda : Opisthobranchia : Nudibranchia)

BY

ULRIKE F. BÜRGIN

552 Palomar Avenue, La Jolla, California

(9 Text figures)

INTRODUCTION

"The highly variable color of the living animals is generally transparent yellowish to bluish-grey, yellow-green or grass-green. The cerata may be translucent like the body, reddish with light blue, green, orange or white specks, probably cutaneous glands. . .The cnidosacs are transparent and separated from the rest of the cerata by a white, orange, yellow, purple or sometimes blue ring. On the outer side of the cerata runs a white line up to this ring. The smooth digestive diverticulum in the ceras is sand-colored, reddish to chocolate-brown, or black."

Reading this description of *Hermissenda crassicornis* (Eschscholtz, 1831) as given by Marcus, 1961, one realizes that it is difficult if not impossible to give a description of the "typical" color pattern in *Hermissenda,* since there is so much variation. However, a careful analysis of a large number of individuals shows that each individual's coloration is composed of the same basic elements according to the same basic rules.

In the first part of this study we shall describe the elements that make up the color pattern, and in the second part we shall consider some of the many color variants and the factors that may be responsible for color variation.

A similar and more extensive study has been done on a European aeolid, *Trinchesia coerulea* (Montagu) (Bürgin, 1961). It is worth noting that, although the two species differ in many details of color pattern, the basic principles of coloration were found to be the same in *Trinchesia* and in *Hermissenda.*

I wish to express my gratitude to all who, through their help and advice, have made this study possible:
To Professor Dr. A. Portmann, University of Basel (Switzerland), for reading the manuscript and helpful criticism; to Professor Dr. E. W. Fager, Scripps Institution of Oceanography, La Jolla (California), and his assistant, Miss Thea Schultze, for lending me optical instruments and laboratory equipment; to Mrs. Fay Wolfson, Mr. Wesley M. Farmer, and Mr. Clinton L. Collier for help with collecting specimens, and to Miss Esther Sandmeier, Zoological Institute of the University of Basel, for making the histological sections.

MATERIAL

Specimens of *Hermissenda crassicornis* were collected at the following locations:

1. La Jolla, rocky area near the "Cove"
   a) at low tide (—0.1 and lower) in tide pools, in May and June, specimens of up to 20 mm were abundant
   b) smaller specimens (up to 10 mm) were found in red algae collected from the rocks at low tide
2. San Diego, Point Loma, in tide pools, specimens up to 20 mm
3. San Diego, Dana Landing, specimens up to 40 mm in June (coll. Farmer & Collier)
4. Ensenada, Baja California, Mexico, in tide pools.

The largest specimens recorded in literature measured 55 mm (O'Donoghue, 1927). The largest specimens in our collection were 40 mm, the smallest ones 3.5 mm. Marcus (1961) gives a detailed account of the morphology and anatomy of the species, which will not be repeated here. However, the following points may be mentioned (Figure 1):

Marcus (*l. c.*) speaks of 11 groups of cerata, and a total of about 500 cerata. In our specimens there was always one distinct group in front of the pericardium, and a second one, equally distinct, behind the pericardium. Posterior to this the cerata of the different groups are so close together as to conceal their arrangement in

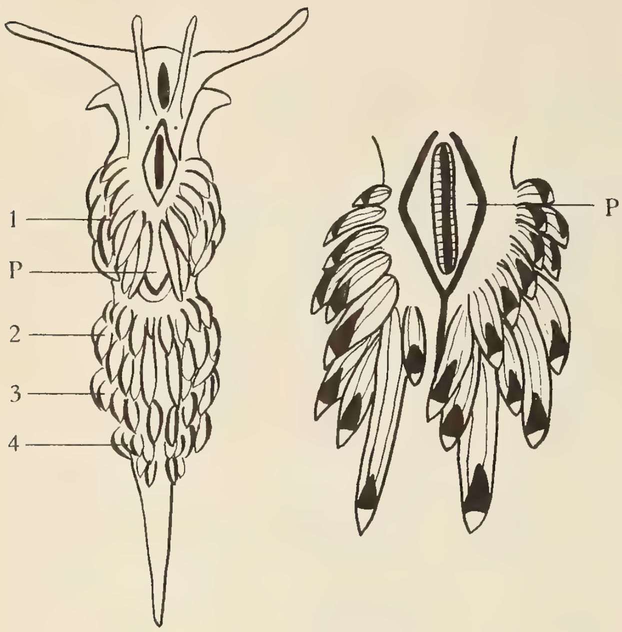


Figure 1: Left - living animal. specimen of 15 mm total length. Right - second group of cerata and pericardium with blue and orange pattern.
P - pericardium 1, 2, 3, 4 - designate groups of cerata

distinct groups. However, if all the cerata were removed, their arrangement in groups could be seen (6 in a specimen of 17 mm total length). The smallest specimen found (3.5 mm) had a total of some 24 cerata arranged in 3 groups. No attempt was made to ascertain the very complicated distribution pattern of the cerata within one group.

The longest cerata are found in the median region of the first two groups immediately in front of or behind the pericardium. It is not always the same pair that is the longest, nor are the longest cerata always corresponding ones on the right and on the left sides, respectively. Some of the median cerata (as well as others) are always in the process of regeneration, being much smaller, and usually hidden among the long cerata.

A. Components of the Color Pattern

Coloration of the ceras: The brown color of the cerata is due to the digestive gland shining through the partly transparent skin. The lower part of the long cerata and most of the smaller ones are dark brown; the upper portions of the longer cerata are lighter brown. Whereas the dark brown color is fairly uniform among all specimens, the lighter parts vary greatly in intensity and color shade, sometimes being almost yellow, in other individuals deep red-brown.

Further observation will show that the light and dark brown colors are due to two different kinds of cells in the digestive gland.

The skin of the cerata contains a varying amount of white, bluish- or greenish-white, light yellow or sky-blue granules. They may be scattered over a large area of the ceras like fine dust or form distinct lines, rings or patches, and they often display a high lustre.

There occurs yet another color, a deep orange, which is a true pigment dissolved in the cells of the epidermis. Where this diffuse orange pigment overlies the patterns formed by the white granules, the latter appear golden yellow.

Coloration of the body: The body pattern consists of blue lines running along the middle of the body and tail, forming two rhomboid patterns, one behind the rhinophores, a second one outlining the pericardium. White or bluish lines also run along the sides of the body between the groups of cerata. They all converge on the tail. Within the first, and sometimes within the second of the rhomboid patterns, and on the sides of the head there are very conspicuous orange markings. The orange patches on the back (though not those on the head) are composed of the same two color elements that were found on the cerata, yellow granules again forming a clear-cut line, the orange pigment being more diffuse, yet more intense in color.

In the laboratory the blue lines described above appear almost white or intensely blue, depending on the background. They show a metallic lustre and are composed of the same kind of granules as the white and blue designs on the cerata. If the animal is observed in one of its natural habitats, the tide pools with their lining of deep green eel grass, the lines on the body and tail appear in a very conspicuous shining green color.

Histological structure of the ceras —

Comparison of living tissues with sections: The ceras of *Hermissenda,* like aeolid cerata in general, has the following structure (Figure 2):

1. The epidermis consists of one layer of vacuolated cells with a thin cuticle and cilia. Between the ordinary epidermis cells gland cells are to be found (Figure 4. The cilia, except those at the tip of the ceras, are usually lost during fixation).

2. Next to the epidermis there is a layer of both circular and longitudinal muscles. The space between this outer layer of skin and muscles and the central digestive diverticulum is occupied by loose strands of connective tissue and filled with blood lacunae. It is this part of the ceras - the muscle layers, connective tissue and blood spaces - that give to the ceras of *Hermissenda* its extreme mobility and capability to contract and extend.

3. The central portion of the ceras is occupied by the diverticulum of the digestive gland with the cnidosac at its tip.

Although our study is confined to the cerata, it may be of general interest to note that in *Hermissenda* the cerata

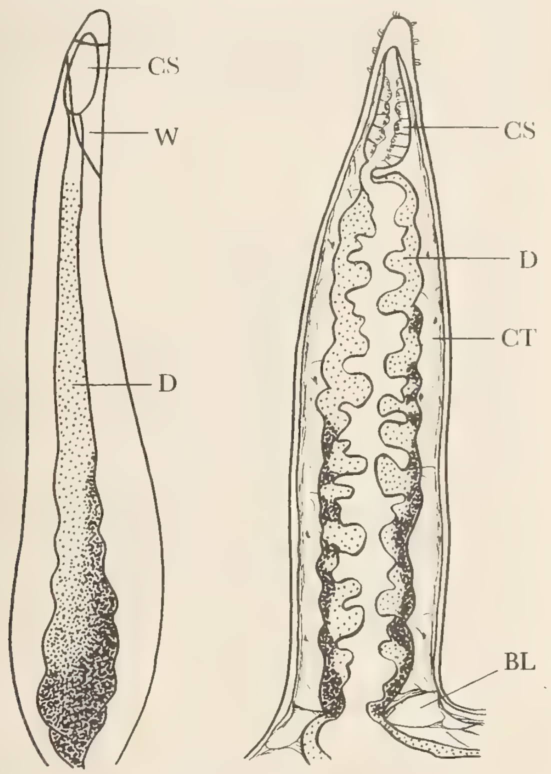


Figure 2: Left - side view of living ceras, showing dorso-ventral symmetry in pigmentation. Right - reconstruction of ceras from several histological sections (Bouin-Azan technique).
BL - blood lacunae
CS - cnidosac
CT - connective tissue
D - digestive diverticulum
W - white granules (sometimes light yellow)

alone contain the glandular tissue of the digestive gland. The ducts in the body are composed of flat, non-glandular epithelium.

In this paper histological details are given only as far as the color pattern is involved. For a more extensive description of the histology of an aeolid ceras the reader is referred to the paper on *Trinchesia* (BÜRGIN, 1961).

Skin pigments (Figures 3 and 4): Both the orange pigment and the white, blue or yellow granules are located in the epidermis. The orange pigment is more or less uniformly dissolved in the vacuoles of the epidermis cells. In cerata with little orange the pigment forms very light patches, leaving some parts entirely uncolored. In some specimens round bodies of deep orange are scattered in the pigmented area. They are located in the muscle layer underlying the epidermis.

The elements producing white, blue or yellow are located in the lower part of the epidermis cells as bodies of various shapes. Histological sections show that they occupy the enlarged basal portion of the cells, the nuclei having a distal position in relation to them. In these structural details *Hermissenda* is similar to *Trinchesia.*

Digestive diverticulum: The digestive epithelium in the ceras is not straight, but forms crypts and folds. The aspect presented by the microscopic preparation of a

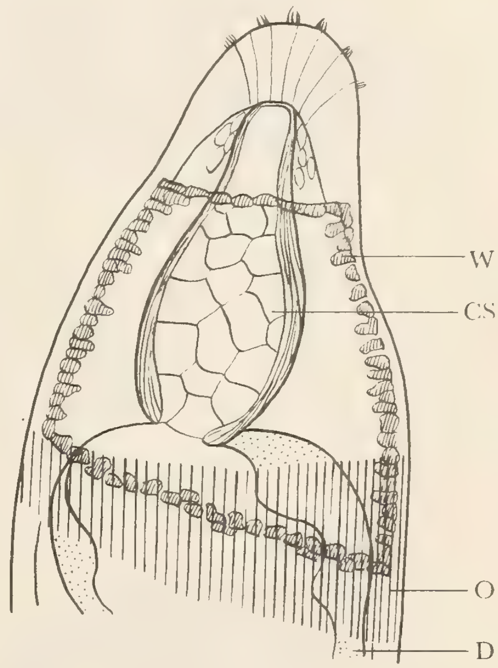


Figure 3: Tip of living ceras (side view), showing white granules and orange pigment (hatched). The white granules are shown only along the edge of the white area, in order to let cnidosac and digestive diverticulum shine through in the central area of the triangle.
CS - cnidosac
D - digestive diverticulum
O - orange pigment
W - white granules (sometimes light yellow)

living ceras is at first confusing. The following types of cells may be discerned in the digestive diverticulum (Figure 5):

a) Cells with thin-walled vacuoles, all of equal size, yellow, ochre, light green, colorless or orange

b) Cells with thin-walled vacuoles of varying size, colors as above except orange.

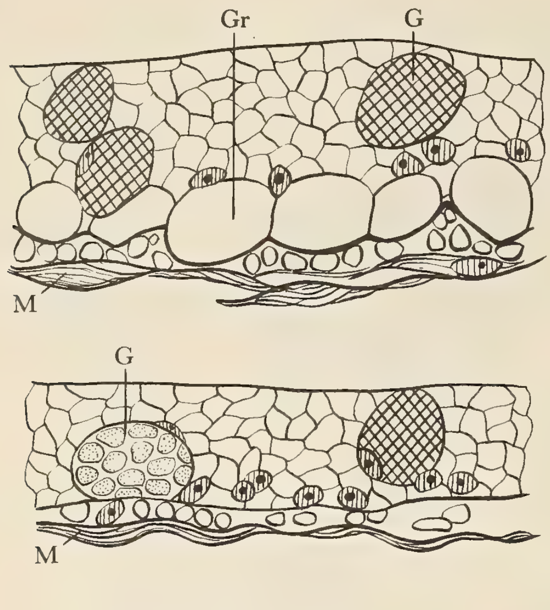


Figure 4: Epidermis of ceras. Histological section (Bouin-Azan). Top - Epidermis from region with white granules. Large holes are seen, where granules were in living tissue. Bottom - Epidermis from non-white area.

G - gland cell
Gr - granule or hole where granule was
M - muscles, circular and longitudinal

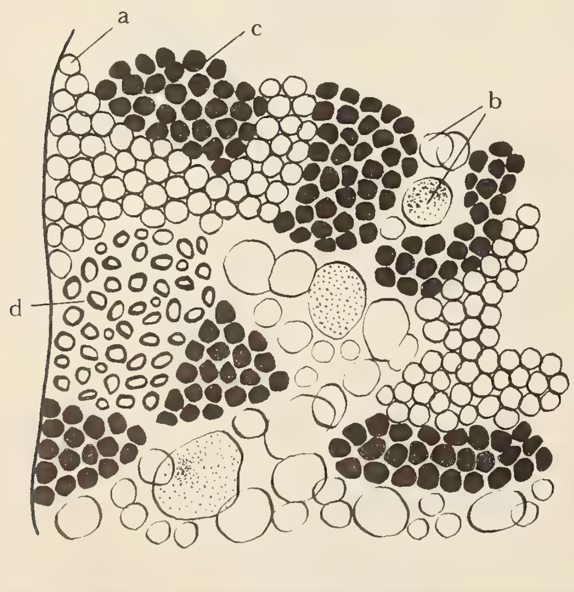


Figure 5: Part of digestive diverticulum of living ceras showing both digestive (a, b) and vacuole cells (c) in different aspects. (Letters refer to descriptions in text)

c) Cells with thick-walled polygonal vacuoles, densely packed, all of equal size, brown or red brown.

d) Cells with brown, purple or colorless granules of irregular shape, smaller than the vacuoles in (c).

In addition large vacuoles and round bodies, either yellow or colorless may be seen circulating in the lumen.

In a histological section fixed with Bouin's fluid and stained with either Hemalum-Benzopurpurine, Azan or Haematoxylin (Prenant) three different kinds of cells are found (Figure 6):

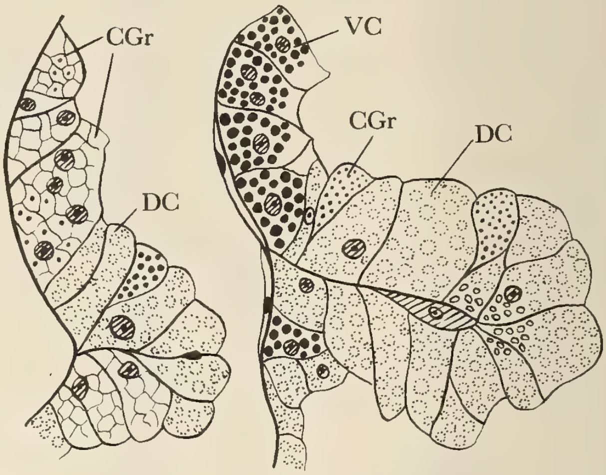


Figure 6: Histological sections of digestive diverticulum (Bouin-Azan). Left - apical part of ceras, no dark granules; in their place are cells with net of vacuoles and few small granules (CGr). Right - basal part of ceras, many vacuole cells with dark granules.

CGr - cell with granules
VC - vacuole cell
DC - digestive cell

1) Club-shaped cells with rounded bodies of equal or varying size, stained blue or orange in Azan, pink in Haemalum, green in Prenant (DC in Figure 6).

2) Cells of pyramidal shape with granules or vacuoles, all of the same size, which are not affected by the staining procedure but retain a dirty yellow or brown color of their own (VC in Figure 6).

3) Club-shaped or, less often, cylindrical or pyramidal cells with a net of vacuoles. Small granules may be found in the vacuoles. The plasma-net is stained orange in Azan; the granules are light brown (probably a color of their own) both in Azan and in Haemalum, but black in Prenant (CGr in Figure 6).

The club-shaped cells with round bodies of equal or varying size (1) are easily identified as the cells described

in the living tissue under (a) and (b). They will be called digestive cells. In many living animals digestive cells filled with vacuoles of an extremely intense orange are found at the base of the ceras. These vacuoles are stained deep red in Azan. All the other color differences often so conspicuous in the living tissue disappear upon fixation.

The pyramidal cells with brown granules (2) of the histological sections correspond to the cells with thick-walled vacuoles (c) of the living ceras. They will be called vacuole cells. Their distribution is characteristic: they are most numerous in the basal part of the ceras; toward the upper portion they become more and more scarce. There may be another cluster of them at the very tip of the digestive diverticulum, or they may be completely lacking there. These cells are more numerous in the dorsal part of the ceras than in the ventral one. They almost invariably occur at the periphery of the digestive diverticulum, in those parts of the crypts oriented towards the outside, the digestive cells occupying the more central parts along the folds.

The nature of the third kind of cells described under (3) in the living tissue and (c) in the histological sections is not clear. These cells are distributed along the entire height of the epithelium.

In *Trinchesia coerulea* two different kinds of cells had been found in the epithelium of the digestive gland, which correspond to the first two types described in *Hermissenda*. They were called "Verdauungszellen" (digestive cells) and "Körnerzellen" (cells with granules, corresponding to the vacuole cells)[1]. According to GRAHAM (1939) the digestive epithelium of aeolids (*Aeolidina, Cratena*) consists of only one type of cell, the digestive cell, which carries out all the major functions of the digestive gland: production and secretion of enzymes, absorption of food, intracellular digestion, production and secretion of both fecal matter and (probably) true excretory products. In the paper on *Trinchesia* the extensive literature on this subject is discussed, and both from references in the literature and from personal observation the conclusion is drawn that the digestive cells in *Trinchesia* only "excrete" fecal matter, whereas the "Körnerzellen" produce true excretory products. These latter cells are considered to represent a cell type of their own.

In the present brief study on *Hermissenda* this question was not investigated any further; yet the general resemblance between the epithelium of *Trinchesia* and that of *Hermissenda* suggests that in *Hermissenda* too the digestive cells carry out all the functions of the digestive gland except the production of excretory substances, the latter being done by the vacuole cells.

The varying aspects of the third kind of cells may perhaps represent different stages in the metabolic cycle of either the digestive cells (production and secretion of enzymes?) or of the vacuole cells (excretion of vacuoles).

Our comparison shows that the digestive cells are responsible for the very variable component in the coloration of the digestive diverticulum. We shall see that their color is directly dependent on the intake of food. The vacuole cells, on the other hand, which impart to the ceras its dark color, retain their color even during long periods of fasting, and the dark brown color is far more constant among individuals feeding on various diets. This is in accordance with the assumption that the metabolic cycle of these cells is relatively independent from that of the digestive cells, and that the contents of the vacuole cells are a particular endproduct of metabolism.

Physical and chemical properties of color-producing structures —

In discussions concerning animal colors, a distinction is generally made between "pigment colors" and "structural colors." Pigment colors are due to a chemical substance (i. e. pigment) that can be extracted and analysed. and that retains its identity and more or less its color under varied conditions.

Structural colors, on the other hand, are due to a physical effect that is produced not by the molecular structure of a pigment, but by certain special structures within the animal tissue, and only under certain defined external conditions such as the incidence of light. These colors disappear or are altered as soon as the special structures or the external conditions are changed.

The orange color found in *Hermissenda* is clearly due to a pigment, for it remains unchanged, whether viewed in reflected or transmitted light, and it can be dissolved (and could be extracted) by organic solvents.

According to the above definition the white, blue and yellow colors in *Hermissenda* and other aeolids are a combination of pigment and structural effect: there is an identifiable substance present in bodies of various shapes, which can be dissolved by certain chemicals. But the specific color of these bodies and their striking metallic lustre are presented only in reflected light. If they are viewed in transmitted light, there is no iridescence, and they appear dull grey-brown instead. The iridescent white, blue and yellow of *Hermissenda* must therefore be due to a structural peculiarity of these bodies.

If these color-structures are viewed in reflected light at low magnifications (10×10), each element has a color of its own. Some of them show a metallic lustre, others do

[1] Cells similar to the third kind in *Hermissenda* were found in *Trinchesia*, but they were less numerous. They were then considered to be a variety of the Körnerzellen.

not. If the light source is moved, the distribution of iridescent and opaque elements is changed. The color that each element shows in transmitted light is roughly complementary to its color in reflected light, blue corresponding to yellow, bluish-green to copper red or purple, and vice versa. In transmitted light very often the margin of each body is yellow or ochre, and its centre either green or purple.

Further magnification of these color-structures (10×40 to 10×100) shows that they are vacuoles with an elastic wall, filled with small particles of oval shape (Figure 7). These small particles are colored yellow, green, blue or purple. Sometimes the particles in one vacuole are all of the same color, sometimes particles of different colors occur in one vacuole, such as yellow ones around the margin, red or green ones in the center.

The same general structure of these vacuoles was observed in *Trinchesia* and a number of other Mediterranean aeolids, and two species of *Glossodoris*. The size of the particles was then determined as follows:

Diameter about 1μ; Thickness $0.4 - 0.5\mu$

Particles of less than 1μ in diameter are often found, and, although more rarely, large ones having a diameter of 2 to 3μ. No measurements were made in *Hermissenda*, but the particles are of the same order of magnitude as in other aeolids.

Vacuoles which are blue or green in transmitted light usually contain larger particles less densely packed than those which have a red color in transmitted light.

In one instance the structure of blue-producing elements on the tail of *Hermissenda* could be seen more clearly than usual: around the margin of the vacuole thin platelets were arranged side by side like the spokes of a wheel. They appeared yellow. The center of the vacuole was red, and small round particles were indistinctly seen.

In the paper on *Trinchesia* the physical principles causing this structural effect are discussed in some detail, and the conclusion is drawn that the yellow and blue color and the metallic lustre of yellow, blue and white in *Trinchesia* are most probably due to interference phenomena.

Interference colors arise when light waves are reflected from the surfaces of thin multiple laminations, which are surrounded by material possessing a contrasting refractive index and whose thickness is of the order of magnitude of the lightwaves. In our case the oval particles about $\frac{1}{2}\mu$ in thickness enclosed in the vacuoles represent the thin laminations. Since these small structures are at the limit of resolution of an ordinary light microscope, it is difficult to obtain information on the exact way of color production. Yet the following observations may be worthy to recorded.

Certain relationships between the color effect and the structure of the vacuole were observed. The color effect produced depends partly on the arrangement and shape of the entire vacuoles and partly on the size of the particles within them. On some of the largest cerata, white of a diffuse, dusty appearance occurs. The color-structures in these areas are slender, widely branched bodies distributed loosely in the skin. Definite lines along the cerata, or the triangles on the tip of the ceras on the other hand are composed of vacuoles of a more compact shape lying close together (Figure 7).

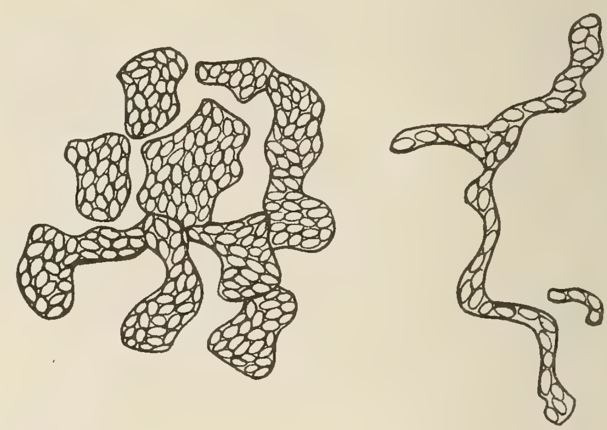


Figure 7: Vacuoles producing iridescent blue, white or yellow, from living ceras.
Left - part of yellow triangle, vacuoles of compact shape
Right - diffuse, dusty white, very slender vacuoles. Within the vacuoles particles producing interference phenomenon are seen.

On the tail of *Hermissenda* both white and blue lines lie side by side. The white is sometimes opaque, sometimes iridescent, the blue is always lustrous. In the opaque white lines vacuoles with very small particles, which are hardly distinguishable at a magnification of 10×100, are crowded very close together. They appear dirty brown in transmitted light, and no color is seen. White with a metallic lustre is produced by vacuoles with larger particles less tightly packed. The individual elements here have the typical colors mentioned above. According to MASON (1926-1927, quoted by Fox, 1953), who observed similar degrees of opaque and iridescent white in butterflies, opaque white is the result of diffuse reflection of light, and iridescence is due to interference.

If vacuoles of all colors are mixed randomly, as in some of the lines on the tail of *Hermissenda*, white is produced. In a blue region, such as the blue lines on the tail and body, and the blue patches on some cerata, most

elements are either plain blue (in reflected light) or green-blue, and yellow or red elements are extremely rare or lacking altogether.

In some specimens of *Hermissenda* yellow lines occur on the cerata below the range of the orange pigment. In these regions vacuoles golden yellow or copper-red in reflected light prevail, and green or blue elements are rare. It must be noted, however, that most of the yellow color seen superficially in *Hermissenda* is either due to the orange pigment combining with white producing structures, or to the effect of the underlying brown digestive diverticulum that gives the white pigment a yellow appearance. At the tip of the ceras, where there is neither orange pigment nor digestive gland, yellow was not found, but only white. In *Trinchesia coerulea,* on the other hand, structures such as those described in *Hermissenda,* produce a golden yellow color which is very intense even if the orange pigment is lacking.

Solubility: The solubility of the color elements in *Hermissenda* was tested (see below). The solubility of the orange pigment in chloroform and in alcohol suggests that it is a carotenoid. The white, yellow and blue color elements, being soluble in dilute acids and alkali, and insoluble in organic solvents, might belong to the group of purines and pterines. No difference in solubility between white and blue regions could be detected. Slight differences between the effect of HCl and NH_4OH on iridescence and dissolution of the vacuoles were observed, but the differences were not consistent. Sometimes the bodies would be dissolved more readily in NH_4OH, sometimes more rapidly in HCl. Table 1 shows that any treatment with chemicals, whether organic or inorganic, immediately alters the structures responsible for iridescence.

Ordinary fixation for histological purposes (Bouin, alcohol) leads to the destruction of both the orange and white or blue colors. The white structures can be preserved if fixing fluids free of acids, such as Helly's fluid, are used. The orange pigment always disappears because of the extensive treatment with alcohol.

B. Variation of the Color Pattern

Description of different variants: One of the most constant features in the pattern of *Hermissenda* is a white or very light yellow triangle at the tip of the ceras, overlying the cnidosac and the most distal part of the digestive diverticulum. The extreme tip of the ceras is always unpigmented. The lower part of this triangle appears golden yellow because of the orange pigment overlying it.

There may be more white, blue or yellow in the region proximal to the triangle. It is the arrangement and color of these color structures that vary most in the cerata of different individuals and even in cerata of a single specimen. There may be:

— a single straight line, or a broken line, white, blue, light yellow or greenish-yellow

Table 1

	Solubility		
	white, blue, yellow structures	orange dissolved in cells	orange bodies in muscle layer
Inorganic Solvents			
1% HCl	structure immediately altered, iridescence disappears, vacuoles dissolved after 10 to 30 minutes	unchanged	color changed, bodies remain
1% NH_4OH	as above	unchanged	unchanged
Organic Solvents			
Chloroform	structure immediately altered, iridescence disappears, vacuoles remain	dissolved	not dissolved within 30 min.
90% Isopropyl alcohol	structure immediately altered, iridescence disappears, white changed to pink! vacuoles remain	dissolved	not dissolved

— a large blue patch covering most of the dorsal side of the ceras
— several white or blue or partly white, blue, light yellow, and greenish patches of irregular shapes
— white granules scattered like fine dust, non-iridescent
— no white, blue or yellow at all.

In Figure 8 are shown a few examples of the various patterns found on the cerata of *Hermissenda*.

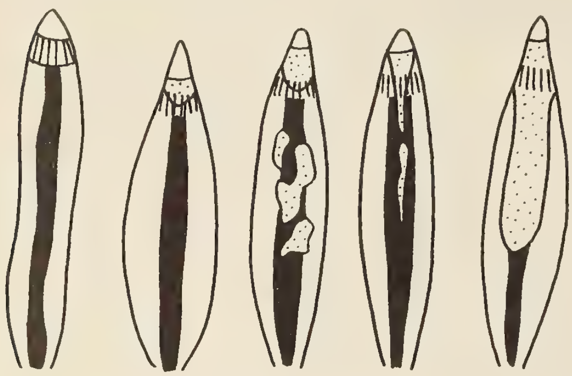


Figure 8: Largest cerata of five different specimens, showing some of many color patterns. Orange = hatched; white or blue = dotted

The intensity and extent of the orange pigment is also variable. The orange may be present only as a narrow ring in the upper zone of the ceras, overlying the region where the digestive diverticulum and the cnidosac meet, or it may extend more than half way down the ceras. In relatively few specimens is it completely lacking.

The digestive diverticulum is usually dark brown at its base. Sometimes the extreme tip is also darker than the middle zone. The color of the middle zone, which is due to the digestive cells and dependent on food will be described in a later section.

Pigment distribution: In the study on *Trinchesia* two general rules concerning the pigmentation of aeolid cerata were stated:

1. The visible, dorsal ("upper") part of the ceras is always more heavily pigmented and carries a more complete color pattern than the invisible, ventral ("lower") part of the ceras. The most conspicuous elements of the color pattern in *Hermissenda*, i. e. the yellow triangle and white or blue lines or patches are confined exclusively to the dorsal part of the ceras. The orange pigment most often extends farther down the ceras on the dorsal than on the ventral side. Even the vacuole cells of the digestive diverticulum, which are responsible for the dark brown color, are much more numerous in the dorsal half of the digestive diverticulum than in the ventral one.

2. The proportions of the color patterns are not the same in cerata of different sizes. Elements of the pattern such as rings, lines, triangles, patches, spots, are relatively larger on small lateral than on long median cerata (the cnidosacs also are proportionately larger in short lateral cerata).

In *Trinchesia* the golden yellow and blue rings could be measured fairly accurately. Since the color pattern in *Hermissenda* is less clear-cut, and the cerata are very mobile and contractile, no such measurements were made. But Figure 8 clearly shows that in *Hermissenda* the yellow triangle is relatively larger on small cerata. The number of vacuole cells too is relatively larger in small cerata. In lateral cerata the entire digestive diverticulum is dark brown, whereas in long median cerata only the basal part and sometimes the tip are dark brown.

Factors influencing coloration: The factors influencing coloration may be roughly stated as follows:

1. Age of specimen
2. Food or other environmental factors
3. Constant features in one individual.

1. Age: In some of the Mediterranean aeolids it is very obvious that as individuals grow they accumulate an increasing amount of those pigments, which are distributed evenly over a large area of the cerata or body, such as the violet in *Coryphella pedata,* the dark brown in *Facelina rubrovittata,* and to a lesser degree the orange in *Trinchesia coerulea,* whereas the relative amount of color-structures, such as the white, blue, or yellow, remains about the same.

It is true that our very small specimens of *Hermissenda* (3 - 5 mm) had little orange pigment, yet there does not seem to be a direct relationship between growth and the increase in orange pigment. Specimens of 10 to 20 mm may have a much deeper orange color than large ones of 30 to 40 mm.

2. Food: In order to study the influence of food on the color of cerata, feeding and regeneration experiments were carried out. Specimens of *Hermissenda* were fed with:

— Cerata or parts of body of other *Hermissenda* (being cannibalistic, the animals have to be kept separately!)
— Various species of hydroids
— *Anthopleura*
— Gonads of sea urchins

In one instance, where a deep red hydroid was used as food, the cerata of *Hermissenda* became distinctly red brown within one or two days. Otherwise a simple change of diet does not produce significant color changes in the cerata.

If normal healthy animals are kept without food for days or even months, the digestive diverticula in the cerata become extremely slender, and the upper light brown part eventually becomes almost transparent. The dark brown color at the base and in the small cerata, however, remains practically unchanged.

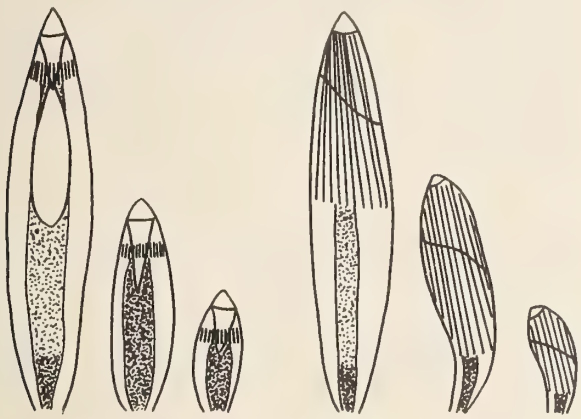


Figure 9: Sets of large, medium and small cerata of two different specimens, showing that color pattern is relatively larger on small cerata. Left - front view; Right - side view. Orange = hatched.

Regeneration: All the large cerata of a healthy animal are removed, and the animal is then kept in fresh sea water that is changed daily, for several days. Even without food the animal will usually regenerate its cerata within about a week or ten days to about one third of the original length. The regenerated cerata are transparent and have almost no color. If the animal is then given food, for example sea urchin eggs, the foodstuff is seen to enter and color the stomach and from there the digestive diverticula within a few hours.

It is the digestive cells of the digestive gland that take in the food particles, and these vary in color according to the food. The dependence of their color on food is a very direct one. The most extreme results were obtained with the orange gonads of sea urchins, and with hydroids, whose endoderm was red, producing yellow or red-brown digestive cells respectively. With the other diets, such as *Hermissenda*-parts, other hydroids or sea anemones the correlation was not as striking.

In contrast to the digestive cells, the contents of the vacuole cells are not influenced in the same degree by the nature of food. The dark elements of the ceras do not appear immediately after the fasting regenerating animal has been fed, but only two days later, and the color of the vacuoles is fairly constant irrespective of the food.

Other environmental factors that might affect the coloration of a specimen, such as water temperature or salinity, were not investigated in the present study.

3. **Stability of individual differences:** Regeneration experiments were carried out in order to determine whether the particular color pattern of an individual is a constant feature in that particular individual, and is reproduced during regeneration in the same way as it had been before.

All the longer cerata of 18 specimens were removed, the characteristics of their color pattern having been recorded. The animals were kept singly in aquaria and fed with cerata of other *Hermissenda* or sea urchin gonads (all specimens were given the same type of food at the same time).

The process of regeneration will briefly be described: Small transparent humps are visible as early as the second day after operation.

On the fourth day tiny cerata with a light brown digestive diverticulum and a transparent cnidosac, but otherwise unpigmented, are present.

About the seventh day the first color structures appear, usually a light-yellow or greenish-white dot at the site of the triangle.

From the tenth day onward some orange pigment may be found.

After two weeks the typical color pattern begins to be recognizable. The distal white elements form a triangle, and there may be some white, yellow or blue basally to it. The cerata have now attained an average length of 2 mm, that is half or two thirds of their original length.

Of the 18 specimens in this particular experiment (some 20 others had been operated on for preliminary experiments to determine the general course of regeneration), 14 survived for two weeks or more after the operation. The longest survival was 30 days. With regard to the color pattern the following results were obtained:

The amount and arrangement of the orange pigment clearly is not fixed individually, but must depend on external factors. In the appearance or lack of blue or white, on the other hand, a certain tendency to produce the same individual pattern as before the operation can be recognized. No blue appeared in specimens which had not had it before the operation, and all those which had possessed a large amount of it originally deposited at least some blue in some of the regenerated cerata. It must be noted, however, that the distribution of blue on the many cerata of an individual is completely random; it is not the same ceras that is marked with blue before and after regeneration, and the shapes of the deposits also vary.

Table 2

	original pattern, before operation	regenerated pattern 14 to 30 days after operation
Blue Color		
6 animals	conspicuous blue on some cerata	blue present on some cerata
4 animals	some blue	some color-structures on cerata basally to triangle, blue or white
4 animals	no blue at all	no blue
Orange		
10 animals	orange present	orange present, but arrangement on cerata different
2 animals	orange absent	orange present
1 animal	very much orange	almost no orange
1 animal	orange	in the same way as before

General remarks on regeneration: The following observations made during these regeneration experiments may be worth recording.

Specimens of *Hermissenda* can survive without food for over a month in the aquarium; they even regenerate their cerata up to a certain point. During this time the tail is resorbed progressively until it is no more than a very short stump. Even if the animals are fed regularly, their tails become shorter during the regeneration process, and the animals decrease in body length as much as 25% (reducing from 20 mm to 15 mm, for example).

In *Trinchesia* we observed that in cerata regenerated without the animal being fed, the structures producing the yellow and blue in the skin appeared, but the fat-soluble orange pigment was lacking. This was considered to be further evidence that the orange pigment is a carotenoid derived from food. In *Hermissenda* the orange pigment does appear in cerata regenerated without food; but the animal seems to have considerable reserves of carotenoids in the body, in the gonads and also in the orange stripes on the back and on the head.

If all the cerata of a *Hermissenda* are removed - they can be picked off easily with watchmaker's forceps - some tiny ones which are too small to be grasped with the forceps, always remain, mostly on the sides, but a few on the back. The latter must have appeared after the loss of a ceras, but were prevented from regenerating as long as all the other ones were present. We observed in fact that if only two median cerata are removed, they never grow longer than one quarter of their original length during the period of one month. If, however, all the other cerata are lost suddenly, these remaining "buds" grow very rapidly during the first days following operation, until they are almost twice as long. Lateral cerata do not grow out of proportion, but the median ones can be recognized as the longest and most developed ones even as long as three weeks after the operation.

A typical example of regeneration is given here.

Length of animal	12 mm
Longest cerata	2 mm
fourth day after operation:	
regenerating cerata	0.5 mm
left-over cerata on back	1.2 mm
left-over cerata on sides	about 1 mm
19th day after operation:	
Length of animal	8 mm
most regenerating cerata	1 - 1.5 mm
left-over cerata on back	2 mm
left-over cerata on sides	about 1 mm

It seems that the cerata which are prevented from regenerating to full length serve as a reserve among the full-grown, functioning ones and take over only if an accident occurs.

SUMMARY

The color pattern of *Hermissenda crassicornis* consists of the following elements:

1. Epidermis
   a) Fat-soluble orange pigment, probably a carotenoid, dissolved in the cells of the epidermis.

b) "Color structures" or granules, soluble in dilute acid and alkali, located in the lower part of the epidermis cells, that produce white, blue or yellow, sometimes iridescent color.

2. Digestive diverticulum
   a) Digestive cells, giving the ceras a light brown, ochre or red brown color, depending on food.
   b) Vacuole cells, dark brown in color, which are less directly dependent on food.

The structure of the white, blue or yellow producing elements is described in some detail. It is assumed that iridescence is due to an interference phenomenon caused by minute particles contained in vacuoles.

Some of the color patterns found most often in cerata of *Hermissenda* are described. The extreme variability of coloration observed in this species is due on the one hand to differences in the amount and distribution of the four basic color elements, and on the other hand to actual color differences of the digestive cells, whose color depends on food.

Feeding and regeneration experiments throw some light on the question as to which features of the color pattern are influenced by external factors, and which are constant in an individual.

LITERATURE CITED

Bürgin-Wyss, Ulrike

1961. Die Rückenanhänge von *Trinchesia coerulea* (Montagu). Rev. Suisse Zool. **68**: 461 - 582; plt.

Fox, Denis L.

1953. Animal biochromes and structural colours. Cambridge Univ. Press; 379 pp.; 3 plts.; 37 text figs.

Graham, Alastair

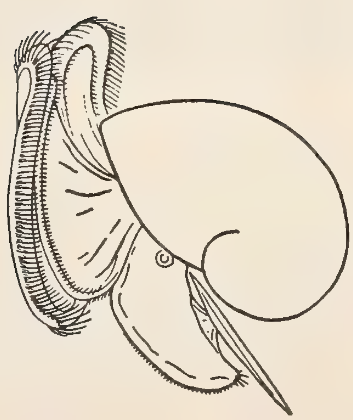
1938. The structure and function of the alimentary canal of aeolid molluscs, with a discussion on their nematocysts. Proc. Roy. Soc. Edinburgh **59**: 267 - 307

Marcus, Ernst

1961. Opisthobranch mollusks from California. The Veliger **3** (Supplement, pt. I): 1-85; plts. 1-10. (Feb. 1, 1961)

O'Donoghue, Charles H.

1927. Notes on a collection of nudibranchs from Laguna Beach, California. Journ. Ent. Zool. Pomona Coll. **19**: 77 to 119; plts. 1 - 3.



Kitchen Midden Mollusks of San Luis Gonzaga Bay

BY

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(Plate 28; 1 Table)

On a collecting trip to San Luis Gonzaga Bay, Baja California, Mexico, in December, 1963, a large Indian midden was observed. The species present in the midden were noted and photographs were taken of what appeared to be figures made on the surface of the ground using arrangements of shells.

After returning to California I learned that Mrs. Faye B. Howard of Santa Barbara had made similar observations during her visit to the same area in May, 1957. Because residents have recently disturbed the deposit by the construction of an air strip (i.e. since Mrs. Howard's visit in 1957), the location of this extensive midden, a list of the species present, and photographs of the figures are put on record.

Midden material occurs along the entire west end of the bay, from the swampy channels on the south to the present settlement on the north. Mrs. Howard visited the southern end of this area, while the members of the 1963 trip camped near the northern end. In the latter area, the midden is underlain by a well consolidated Late Pleistocene marine deposit, while the midden itself is loosely consolidated and contains typical midden species.

Three published reports include lists of the shells in Indian middens in the Gulf of California area; they are: Gifford (1946) on Puerto Peñasco, Schenck & Gifford (1952) on San Felipe, and Emerson (1960) on San José Island. The first two lists were published prior to Keen (1958), and some names of the mollusks do not agree with current usage. In order to bring these two lists up to date, and for purposes of comparison, the three lists are added to mine from San Luis Gonzaga Bay (see Table 1). Schenck & Gifford (*l. c.*) gave no measure of species-frequency.

This table gives an indication of the relative abundance of the various species used as food by Indians throughout the area of the Gulf of California. It is probable that most of the small and uncommon gastropods were attached to pelecypods or picked up out of curiosity. The only gastropods that seem to have been of importance are *Muricanthus nigritus* and *Strombus gracilior*. There are many species of clams, which formed an important item in the Indian diet.

Figures 1 and 2 (Plate 28) show the midden and some of the species contained in it. Of the species present in the San Luis Gonzaga midden, only *Trachycardium consors* has not recently been collected in the bay and has not been reported north of Bahía de Los Angeles, Baja California.

Two similar figures were observed in 1963, and one of these is illustrated here (Figure 3, Plate 28). Because the figure is on the crest of a hill, a clear perspective could not be achieved, and the representation, presumably that of a man, is indistinct. The other figure, a few feet away, was not photographed. Both were surprisingly clear when seen in the field. Mrs. Howard cleared the area

Explanation of Plate 28

Figure 1: Midden on west side of San Luis Gonzaga Bay. The most abundant species is *Strombus gracilior*.

Figure 2: Close-up of midden surface, showing valves of *Glycymeris gigantea*, two fragments of *Muricanthus nigritus* (center and left), and one specimen of *Strombus gracilior* (left).

Figure 3: Human figure made with *Strombus gracilior*. Cluster in background represents head; body is in foreground.

Figure 4: Figure of a fish. Surrounding area has been cleared of other shells and rocks. The figure is composed of *Anadara multicostata* (tail), *Strombus gracilior* (most of body), *Muricanthus nigritus* (center of foreground), *Dosinia ponderosa* (on either side of *Muricanthus*, and *Pecten vogdesi* (to right of rightmost *Dosinia* valve). Figures 1 and 4 were taken by Mrs. Faye Howard in May, 1957, while figures 2 and 3 were taken by the author in December, 1963. All four figures are reproductions from kodachrome slides.

Figure 1

Figure 2

Figure 3

Figure 4

around the one that she photographed (Figure 4, Plate 28). It apparently represents a fish.

It is possible that these figures are of later origin than the midden. The shells used in the drawings are species common throughout the midden. The figures seen in 1963 were partially overgrown with vegetation, and each shell was half-buried in sand.

LITERATURE CITED

EMERSON, WILLIAM K.

1960. Results of the Puritan-American Museum of Natural History Expedition to Western Mexico, 12: Shell middens of San José Island. Am. Mus. Novitates, No. 2013: 1 - 9, 4 figs. (18 August 1960)

GIFFORD, E. W.

1946. Archaeology in the Punta Peñasco Region, Sonora. Am. Antiquity **11** (4): 215 - 221; 1 fig. (April 1946)

KEEN, A. MYRA

1958. Sea shells of tropical west America; marine mollusks from Lower California to Colombia. Stanford Univ. Press, xi + 624 pp.; illus. Stanford, Calif.

SCHENCK, W. EGBERT & E. W. GIFFORD

1952. Archaeological sites on opposite shores of the Gulf of California. Am. Antiquity **17** (3): 265. (January 1952)

Table 1: Indian Midden Mollusca

	P. P.[1]	S. F.[2]	S. L. G.[3]	S. J. I.[4]
PELECYPODA				
Arca pacifica (SOWERBY, 1833)	1	x	5	
Barbatia reeveana (D'ORBIGNY, 1846)				8
Anadara formosa (SOWERBY, 1833)				7
Anadara multicostata (SOWERBY, 1833)			6	
Glycymeris gigantea (REEVE, 1843)			6	7
Glycymeris maculata (BRODERIP, 1832)	2	x		7
Glycymeris multicostata (SOWERBY, 1833)				8
Mytella guyanensis (LAMARCK, 1819)	2			
Modiolus capax (CONRAD, 1837)		x	4	7
Pteria sterna (GOULD, 1851)	1	x		
Pinctada mazatlanica (HANLEY, 1856)				9
Ostrea angelica ROCHEBRUNE, 1895	3	x		9
Ostrea fisheri DALL, 1914				9
Ostrea palmula CARPENTER, 1856		x		
Pecten vogdesi ARNOLD, 1906			4	9
Aequipecten circularis (SOWERBY, 1835)				9
Lyropecten subnodosus (SOWERBY, 1835)			4	9
Spondylus sp. (unidentifiable)			4	
Spondylus princeps BRODERIP, 1833				9
Anomia peruviana D'ORBIGNY, 1846				7
Cardita affinis californica DESHAYES, 1854	2	x		7
Chama buddiana C. B. ADAMS, 1852	1	x		
Chama frondosa BRODERIP, 1835	3	x		9
Trachycardium consors (SOWERBY, 1833)			5	8
Trachycardium panamense (SOWERBY, 1833)	1	x		
Trigoniocardia biangulata (BRODERIP & SOWERBY, 1829)				7
Laevicardium elatum (SOWERBY, 1833)	2	x	6	
Periglypta multicostata (SOWERBY, 1835)				7
Megapitaria squalida (SOWERBY, 1835)			4	8
Dosinia ponderosa (GRAY, 1838)	2	x	6	
Chione californiensis (BRODERIP, 1835)	3		6	9
Chione undatella (SOWERBY, 1835)			4	8

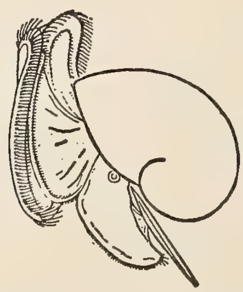
	P. P.[1]	S. F.[2]	S. L. G.[3]	S. J. I.[4]
Chione fluctifraga (SOWERBY, 1853)	1	x		
Protothaca grata (SAY, 1831)	1	x	4	
Tagelus affinis (C. B. ADAMS, 1852)	2			
Tagelus californianus (CONRAD, 1837)		x		
GASTROPODA				
Diodora inaequalis (SOWERBY, 1835)				7
Tegula mariana DALL, 1919		x		8
Tegula rugosa (A. ADAMS, 1853)		x		
Turbo fluctuosus WOOD, 1828	1	x		
Turbo squamiger REEVE, 1843				8
Cerithium maculosum KIENER, 1841				7
Cerithium stercusmuscarum VALENCIENNES, 1833				7
Crepidula cf. *C. onyx* SOWERBY, 1824				7
Crucibulum scutellatum (WOOD, 1828)		x		
Crucibulum spinosum (SOWERBY, 1824)				7
Polinices reclusianus (DESHAYES, 1839)		x	4	
Cypraea annettae DALL, 1909				7
Strombus galeatus SWAINSON, 1823			4	7
Strombus gracilior SOWERBY, 1825			6	
Strombus granulatus SWAINSON, 1822				7
Muricathus sp. (unidentifiable)				7
Muricanthus nigritus (PHILIPPI, 1845)	3	x	6	
Acanthina angelica I. OLDROYD, 1918		x		
Anachis coronata (SOWERBY, 1832)				7
Cantharus macrospira (BERRY, 1957) (?) as "*Solenosteira anomala*"		x		
Melongena patula (BRODERIP & SOWERBY, 1829)	1			
Oliva incrassata (SOLANDER, 1786)	1	x		
Conus princeps LINNAEUS, 1758				7

[1] Puerto Peñasco (GIFFORD, 1946)
1 = found in one site 2 = found in two sites
3 = found in three sites

[2] San Felipe (SCHENCK & GIFFORD, 1952)
x = present, no quantitative measure given

[3] San Luis Gonzaga Bay
4 = present 5 = common 6 = very common

[4] San José Island (EMERSON, 1960)
7 = rare or uncommon 8 = common 9 = very common



Cypraea: A List of the Species

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OF INTEREST TO COLLECTORS, malacologists, students, specialists, and others, is a definitive list of the living species comprising the genus *Cypraea s.l.* This field is, unfortunately, a rather fluid one, and specific names flit in and out, appear, then disappear into synonymy with disconcerting frequency. It is probably not fair to place the entire blame for this state of affairs on the controversy between the splitters and the lumpers, because the ever increasing activity of collectors in the field continually makes additional material available to the specialists for analysis and study. The literature on *Cypraea* is, as is well-known, vast, scattered, and confusing, and it is accordingly impossible, indeed, inadvisable, to attempt a complete review of all of the developments which have taken place since the original enumeration of the genus by LINNAEUS. We choose, instead, as a starting point, the familiar Prodrome of the SCHILDERS (1938 - 1939). In this paper, which is still a standard reference, 165 species were listed. Some, but not all, of the developments since then are traced below, with the emphasis, of course, placed on the work of SCHILDER.

In 1940, in a paper on the distribution and abundance of Cypraeidae, the SCHILDERS (1940a) listed the same 165 species, but in a drastically altered systematic order. It seems appropriate to point out that this revised order is the one used by the SCHILDERS in their subsequent publications, and that, notwithstanding, the previous order used by them in the Prodrome is the one usually used by other authors up to the present time.

The SCHILDERS (1940b) then increased the number of species to 171 by elevating 6 former subspecies to specific rank. These are: *listeri* (from *felina*), *acicularis* (from *spurca*), *eburnea* (from *miliaris*), *succincta* (from *onyx*), *tortirostris* (from *chinensis*), and *thersites* (from *friendii*).

Shortly thereafter SCHILDER (1941), in a paper on the affinity and distribution of Cypraeacea, tabulated the large number of known fossil and recent examples of the superfamily, and at the same time reduced the number of living species of *Cypraea s. l.* to 156 by lowering 15 former species to subspecific rank. These are: *acicularis* (into *spurca*), *eburnea* (into *miliaris*), *succincta* (into *onyx*), *tortirostris* (into *chinensis*), *thersites* (into *friendii*), *maculifera* (into *histrio*), *broderipii* (into *nivosa*), *leviathan* (into *carneola*), *macandrewi* (into *beckii*), *gambiensis* (into *zonaria*), *petitiana* (into *pyrum*), *nigropunctata* (into *arabicula*), *comptoni* (into *piperita*), *mayi* (into *angustata*), and *hesitata* (into *armeniaca*). It may be noted that the first five of these pairs are among the six which had just previously been split (see preceding paragraph).

Somewhat later, STEADMAN & COTTON (1946) published a key to the subfamilies and genera of Cypraeidae, and addended a systematic list of 172 species. The order in this list is roughly that used by the SCHILDERS (1938 to 1939); the differences in the assignments among the genera need not concern us here. What is of interest, on the other hand, is the increase of seven in the number of species over the 165 listed in the Prodrome of the SCHILDERS. Unfortunately, this increase is not due merely to the splitting off of seven subspecies by STEADMAN & COTTON. Detailed analysis of the two lists shows that STEADMAN & COTTON included 26 taxa as species which were either unknown to or ignored by the SCHILDERS, or which they classed as subspecies or synonyms. Conversely, the SCHILDERS included 19 taxa as species which STEADMAN & COTTON either classed as subspecies or relegated to the synonymy of other species. It is this rather messy situation which leads to the net increase of seven mentioned above. The classification of STEADMAN & COTTON follows closely that of others of the Australian school - notably IREDALE - and it has not won universal acceptance. For this reason, interesting though they may be, the individual differences between the list of STEADMAN & COTTON on the one hand and that of the SCHILDERS on the other hand will not be detailed here. It would seem, however, that the total number of these differences is considerably larger than one would expect to find between different authorities.

In the next catalog of the SCHILDERS (1952[2]) the 165 species listed are identical with those of the Prodrome.

[1] Contribution No. 267.

[2] Written in 1940, but (due to WW II) not published until 1952.

The compilation by ALLAN (1956) includes approximately 171 species. This work follows closely the list and arrangement of STEADMAN & COTTON, but does not always make it clear just what her analysis of the situation is. She apparently assigns specific rank to five subspecies of STEADMAN & COTTON, while at the same time reducing seven of the species of the latter to subspecies or synonyms. ALLAN also adds one species, *rosselli,* which had been established after the paper of STEADMAN & COTTON by COTTON (1948). [Note: The reference in SCHILDER (1961 a) for the original description of *rosselli* is incorrect.]

The subspecies *aequinoctialis* was split from *annettae* by SCHILDER (1958). [Note: The date 1938 for this reference as given in SCHILDER (1961 a) is apparently a misprint.]

Next, SCHILDER (1961 a) listed the new names accepted by him since the publication of the Prodrome. These include one name change, viz., from the preoccupied *arenosa* GRAY to *schilderorum* IREDALE, the elevation of *aequinoctialis* out of *annettae,* two admissions of former synonyms as species, viz., *ostergaardi,* distinct from *helvola,* and *latior,* distinct from *teres,* and nine newly described species, viz., *langfordi, teramachii, episema, hammondae, euclia, rosselli, wilkinsi, katsuae,* and *raysummersi.* The total increase over the number of species listed in the Prodrome is thus eleven.

GRIFFITHS (1961) then proposed a revision of the subgenus *Notocypraea.* He increased the four *Notocypraea s.l.* of SCHILDER (1941) to ten by adding the species *comptonii, dissecta, emblema, euclia, moelleri,* and *wilkinsi* to the list.

As a part of a discussion of size variations in cowries, SCHILDER (1961 b) presented a list of 176 species which was stated to "have been arranged, with some slight emendations, according to the writer's last catalog (SCHILDER, 1941)." It will be recalled that this last catalog contained 156 species; the "slight emendations" (aside from some minor changes in the systematic order) are: deletion of one species, viz., *waikikiensis,* addition of five new species, viz., *rosselli, ostergaardi, langfordi, teramachii,* and *raysummersi;* elevation of 16 subspecies, viz., *thersites* (from *friendii*), *maculifera* (from *histrio*), *broderipii* (from *nivosa*), *leviathan* (from *carneola*), *margarita* (from *cicercula*), *macandrewi* (from *beckii*), *tomlini* (from *cernica*), *acicularis* (from *spurca*), *eburnea* (from *miliaris*), *gambiensis* (from *zonaria*), *aequinoctialis* (from *annettae*), *petitiana* (from *pyrum*), *nigropunctata* (from *arabicula*), *reticulifera* (from *declivis*), and *bicolor* and *comptonii* (from *piperita*); the overall increase in the number of species is accordingly 20. It should be pointed out that of the above 15 subspecies now classed as species, 11 were among the 15 previously demoted from specific to subspecific rank by SCHILDER (1941); it is therefore obvious that there is a total difference of opinion with regard to eight species-subspecies in the two lists. Furthermore, of the nine new species accepted by SCHILDER (1961 a), only four are included in SCHILDER (1961 b); those omitted are: *episema* (included in *venusta*), *hammondae* (possibly included in *raysummersi* - even though *hammondae* is the prior name), *euclia* and *wilkinsi* (a revision of *Notocypraea* is promised), and *katsuae* (which simply vanished).

Somewhat later, SCHILDER (1961 c) pointed out some additions to the earlier paper (SCHILDER, 1961 a). These include recognition of *luchuana* and *katsuae* as species, withholding recognition of the specific status of the recently described *kuroharai* and *musumea* as species (Die Abbildungen . . . sind mir z. Zeit noch unzugänglich"), and a short discussion of the situation with regard to *Notocypraea.*

The list of species compiled by GRIFFITHS (1962) numbers 185. Referring back to the Prodrome, we find that the following twelve have been added: *langfordi, teramachii, wilkinsi, euclia, musumea, raysummersi, hammondae, katsuae, luchuana, episema, rosselli,* and *kuroharai;* the following ten former subspecies or synonyms have been elevated: *thomasi* (from *macandrewi*), *ostergaardi* (from *helvola*), *aequinoctialis* (from *annettae*), *molleri* (from *angustata*), *emblema* (from *angustata*), *dissecta* (from *piperita*), *latior* (from *teres*), *tortirostris* (from *chinensis*), *thersites* (from *friendii*), and *contraria* (from *friendii*); furthermore *mayi* is considered a synonym of *comptonii,* and *waikikiensis* has disappeared into unspecified synonymy.

More recent activity includes the following proposals:

SCHILDER (1962 a) nominated *titan* as a new species. It is a large African form of *carneola,* but said to be specifically distinct from it.

SCHILDER (1962 b) elevated *luchuana* to specific status, and placed it intermediate between *pallidula* and *quadrimaculata.*

SCHILDER (1963 a) nominated *catei* as a new species. The unique shell had previously been recorded as *venusta* (CATE, 1962).

SCHILDER & SUMMERS (1963) nominated *casta,* a white, unspotted form recalling *comptonii,* as a new species. As an example of the vicissitudes of a new species, the subsequent chronicle of *casta* is of rare interest.

GRIFFITHS (1963) came to the conclusion on the basis of the examination of 25 shells from the same locality, that it was likely that the tendency to albinism (of the

form called *casta*) was a function of environment alone, and that it did not merit taxonomic separation (from *comptonii*).

Schilder (1964a) then replied on the basis of certain characteristics of 39 specimens, that *casta* was not an extreme variant of *comptonii,* but rather a mutant deserving of taxonomical separation (at the species level as implied by the title of the paper).

Brand (1964) reported the results of the examination of 26 specimens, and concluded that there was an uninterrupted series from the "dark end" of *comptonii* to the "white end" of *casta,* but then, curiously, stated that the name *casta* was essential for clarity even if it did not represent a true species.

Griffiths (1964a) then asserted, after a short discussion of the statistical data of Schilder (1964a) and Brand (1964) that it was not possible to accept the name *casta* for clarity, as Brand suggested, unless the species were accepted, but that the International Rules clearly forbade that position.

Finally (it is to be hoped), Schilder (1964b) demoted *casta* from specific rank to that of, in his notation, an infraspecies of a subspecies (*comptonii*) of the species *piperita.*

A new species, *dayritiana,* was nominated by Cate (1963). It was described as being related to *coxeni, luchuana, pallidula, interrupta,* and *quadrimaculata,* but, of course, specifically distinct from them.

The total number of living cowrie species was then placed at 170 by Schilder (1963b) in a paper on nomenclatorial problems. This number was stated to have been arrived at by adding the number of cowrie species discovered since 1941 to those in "my last catalog", i. e., Schilder, 1941. The number of living species in Schilder (1941) is 156; it therefore follows that Schilder considers that 14 species were discovered since then, unless the number 170 is a misprint. There is an obvious discrepancy here, because the number of species listed in Schilder (1961b) is 176. A possible explanation here is that the "170" of Schilder (1963b) should read "180", in which case four species described since 1961 must be added to the list of Schilder (1961b). It just so happens that four new species were in fact created during that period, viz., *titan, luchuana, catei,* and *dayritiana* (see above).

The status of *kuroharai* and *katsuae* was then discussed by Schilder (1963c) in a short paper, in which they both were recognized as species. In this same paper *musumea* was said to be indistinguishable from *katsuae.*

The list of Cernohorsky (1963) enumerates 186 species, with two more added in the Addenda. The excess of eight over 180 comes about as follows: Cernohorsky reduces *tomlini* and *acicularis* to subspecies (of *cernica* and *spurca* respectively), but adds ten species by accepting the ten *Notocypraea* of Griffiths (1961) in place of the seven of Schilder (1963), listing *hesitata* as distinct from *armeniaca, raysummersi* as distinct from *hammondae, tortirostris* as distinct from *chinensis, summersi* as distinct from *pallidula,* and accepts *katsuae, kuroharai,* and *musumea.* The situation is not quite that simple, however, for Cernohorsky, at the end of his list, classes *aequinoctialis, armeniaca, latior, listeri, raysummersi, titan* and *tortirostris* as "doubtful *Cypraea* species." To further complicate things, this list of doubtful species, which comes after the presumably definitive list, is inconsistent with some of the "notes" which follow. It is mentioned in the notes that further research is necessary in the case of *armeniaca,* stated that it is doubtful that *latior* is a valid species, and suggested that *raysummersi* might prove to be a subspecies of *hammondae.* (The same opinion was recently attributed to R. H. Summers by an anonymous (1963) author. On the other hand, Griffiths (1964b) expressed the opinion that *hammondae* and *raysummersi* were both distinct, valid species, on the basis of considerable and distinct differences between them.) Moreover, Cernohorsky does not give his reasons for the doubts concerning *aequinoctialis* and *listeri,* the questioning of *tortirostris* is equivocal, and, finally, *titan* is not questioned, but accepted. Even more contradictory is the rejection, in the notes, of species not included in the "doubtful" category, viz., *margarita* and *musumea,* and the implication that *katsuae* is the Japanese race of *hammondae; margarita,* which was considered a subspecies by the Schilders in the Prodrome, in 1940a and 1940b, and by Schilder in 1941, but elevated by him in 1961b, is considered by Cernohorsky to be merely an extreme variant of *cicercula,* an opinion with which Schilder, in a private communication, is stated to concur, while *musumea* is stated "with all probability" to be identical with *katsuae* (the reasons why Cernohorsky retained *margarita* and *musumea* in his list are not given). With regard to *summersi,* to which Cernohorsky accords specific status, additional (later) opinions support this conclusion, such as those of R. H. Summers (see Anonymous 1963) and Cernohorsky (1964a and 1964b).

The *Notocypraea* tangle was recently unravelled by Schilder (1964b), who allowed four or five species, namely, *pulicaria, bicolor, piperita, angustata,* and, possibly, *declivis.*

Schilder & Schilder (1964) then listed 160 species, as well as 41 "well-recognizable" subspecies, in an interesting paper which gives the lengths of the largest and smallest

known examples of each species. The systematic order, with a number of minor rearrangements, follows that of SCHILDER (1961 b). It should be noted that the total of 160 differs not only from the 176 of SCHILDER (1961 b), but also from the 170 (conjectured above, apparently erroneously, to be a misprint for 180) of SCHILDER (1963 b). The decrease of 16 from 176 to 160 comes about as follows: four new species, *catei, rabaulensis, katsuae,* and *luchuana,* are added; one former subspecies, *superstes* is accorded specific status (split from *martini*); one species, *leviathan,* disappears from the list (and hence is not now considered an even well-recognizable subspecies); and 20 species are demoted to subspecies, *mexicana* into *isabella, cervinetta* into *cervus, obvelata* into *annulus, tomlini* into *cernica, ostergaardi* into *boivinii, acicularis* into *spurca, nebrites* into *erosa, eburnea* and *lamarcki* into *miliaris, granulata* into *nucleus, gambiensis* into *zonaria, petitiana* into *pyrum, aequinoctialis* into *annettae, reticulifera* (as *occidentalis*) into *bicolor, comptonii* into *piperita, declivis* into *angustata, listeri* into *felina, latior* into *rashleighana, subteres* into *teres,* and *coloba* into *chinensis.* It is interesting that *dayritiana* is classed as a subspecies of *luchuana, raysummersi* as a subspecies of *hammondae,* that *titan* and *summersi* do not even appear as "well-recognizable" subspecies, and that *margarita* is listed as a distinct species. Finally, a species accepted in 1963, *kuroharai,* is not on the list.

The list of WAGNER & ABBOTT (1964) contains 163 species of *Cypraea,* in alphabetical order. As might be expected, the difference of three between this list and the 160 species of SCHILDER & SCHILDER (1964) does not arise in a simple way. Analysis of the two lists reveals the following differences: relative to the species of the SCHILDERS, WAGNER & ABBOTT consider 14 of them subspecies, viz., *artuffeli* (of *clandestina*), *bicolor* (of *piperita*), *catholicorum* (of *esontropia*), *diluculum* (of *ziczac*) *erythraeensis* (of *stolida*), *grayana* (of *depressa*), *hammondae* (of *gracilis*), *kieneri* (of *ursellus*), *luchuana* (of *pallidula*), *macandrewi* (of *beckii*), *margarita* (of *cicercula*), *minoridens* (of *microdon*), *owenii* (of *ursellus*), *and serrulifera* (of *microdon*); in addition, *ovum* is included in the synonymy of *errones, fuscodentata* in that of *angustata, superstes* in that of *martini,* and *catei* in that of *venusta,* while four names not in the SCHILDER-SCHILDER list are used: *coffea* (considered by SCHILDER & SCHILDER (1938) a synonym of *ursellus*), *darwini* (apparently a sub-fossil specimen of *nigropunctata,* according to SCHILDER (1961 a)), *facifer* (a subspecies of *limacina* in SCHILDER & SCHILDER (1938)), and *verconis* (a subspecies of *angustata* in (1964 b)). [Note: WAGNER & ABBOTT use *angustata* for the South African species called *fuscodentata* by SCHILDER, and *verconis* for the South Australian species called *angustata* by SCHILDER.] Furthermore, WAGNER & ABBOTT assign specific rank to the following 18 taxa classed as subspecies by SCHILDER & SCHILDER (1964): *casta, cervinetta, coloba, declivis, eburnea, granulata, hesitata, kuroharai, lamarckii, latior, moelleri, musumea, ostergaardi, raysummersi, thomasi, titan, tomlini,* and *wilkinsi.* It is interesting that nine of these are among the 20 recently demoted by the SCHILDERS (1964), and that WAGNER & ABBOTT really give ambiguous status to *casta* ("may be *comptoni*"), *raysummersi* ("may be *hammondae*"), and *titan* ("probably large *carneola* with aberrant radula"). Finally WAGNER & ABBOTT make no mention of *rabaulensis*: one suspects that this is the unique, undescribed specimen alluded to by Summers (see ANONYMOUS, 1963). This suspicion is confirmed by the recent paper by SCHILDER (1964 c) in which *rabaulensis* is nominated as a new species, on the basis of a unique specimen in the Summers collection.

CONCLUSION

As must be obvious from the foregoing discussion, it is not possible at the present time - indeed, one doubts whether it will ever be possible - to devise a definitive list of the species of living *Cypraea.* It is probably expecting too much to hope that unanimity will ever be attained among the numerous authorities. Accordingly, we present four lists: first, 142 "non-controversial" species recognized both by SCHILDER (1964) and by WAGNER & ABBOTT (1964); second, 18 "provisional" species recognized by SCHILDER, but not by WAGNER & ABBOTT; third, 18 "provisional" species definitely recognized by WAGNER & ABBOTT but not by SCHILDER; and fourth, 29 "controversial" species, i. e., most of those which at one time or another during the past quarter century have been accorded specific status. Following each entry in the second, third, and fourth lists is given, in parentheses, the species of List One to which each of the subspecies or synonyms(as presently considered) comprising these three lists is assigned. In view of the past history of this field, it should not be surprising to find, at some future date, some of the occupants of the last three lists transferred to List One (or vice versa). Because the systematic arrangement is in a state of flux, the order in all four lists is alphabetical, for easy reference.

LIST ONE

Non-controversial species

achatidea	*caurica*	*felina*	*leucodon*	*picta*	*subviridis*
albuginosa	*cernica*	*fimbriata*	*limacina*	*piperita*	*sulcidentata*
algoensis	*cervus*	*friendii*	*lurida*	*poraria*	*surinamensis*
amphithales	*childreni*	*fultoni*	*lutea*	*pulchella*	*talpa*
angustata	*chinensis*	*fuscodentata*	*lynx*	*pulchra*	*teramachii*
annettae	*cicercula*	*fuscorubra*	*maculifera*	*pulicaria*	*teres*
annulus	*cinerea*	*gangranosa*	*mappa*	*punctata*	*tessellata*
arabica	*citrina*	*gaskoini*	*marginalis*	*pyriformis*	*testudinaria*
arabicula	*clandestina*	*globulus*	*marginata*	*pyrum*	*teulerei*
argus	*contaminata*	*goodalli*	*mariae*	*quadrimaculata*	*thersites*
armeniaca	*coxeni*	*gracilis*	*martini*	*rashleighana*	*tigris*
asellus	*cribellum*	*guttata*	*mauritiana*	*reevei*	*turdus*
aurantium	*cribraria*	*helvola*	*microdon*	*robertsi*	*ursellus*
barclayi	*cumingi*	*hirasei*	*miliaris*	*rosselli*	*valentia*
beckii	*cylindrica*	*hirundo*	*moneta*	*sanguinolenta*	*ventriculus*
bistrinotata	*decipiens*	*histrio*	*mus*	*saulae*	*venusta*
boivinii	*depressa*	*hungerfordi*	*nigropunctata*	*schilderorum*	*vitellus*
broderipii	*dillwyni*	*interrupta*	*nivosa*	*scurra*	*vredenburgi*
camelopardalis	*edentula*	*irrorata*	*nucleus*	*semiplota*	*walkeri*
capensis	*eglantina*	*isabella*	*ocellata*	*spadicea*	*xanthodon*
caputdraconis	*erosa*	*katsuae*	*onyx*	*spurca*	*zebra*
caputserpentis	*errones*	*labrolineata*	*pallida*	*staphylaea*	*ziczac*
carneola	*esontropia*	*langfordi*	*pallidula*	*stercoraria*	*zonaria*
	exusta	*lentiginosa*	*pantherina*	*stolida*	

LIST TWO

"Provisional" species, recognized by Schilder

artuffeli (clandestina)	*luchuana (pallidula)*
bicolor (piperita)	*macandrewi (beckii)*
catei (venusta)	*margarita (cicercula)*
catholicorum (esontropia)	*minoridens (microdon)*
diluculum (ziczac)	*ovum (errones)*
erythraeensis (stolida)	*owenii (ursellus)*
grayana (depressa)	*rabaulensis*
hammondae (gracilis)	*serrulifera (microdon)*
kieneri (ursellus)	*superstes (martini)*

LIST THREE

"Provisional" species, not recognized by Schilder

cervinetta (cervus)	*kuroharai (schilderorum)*
coffea (ursellus)	*lamarckii (miliaris)*
coloba (chinensis)	*latior (rashleighana)*
darwini (nigropunctata)	*moelleri (angustata)*
declivis (angustata)	*musumea (katsuae)*
eburnea (miliaris)	*ostergaardi (boivinii)*
facifer (limacina)	*thomasi (macandrewi)*
granulata (nucleus)	*tomlini (cernica)*
hesitata (armeniaca)	*wilkinsi (bicolor)*

LIST FOUR

Controversial species

acicularis (spurca)	*listeri (felina)*
aequinoctialis (annettae)	*mayi (piperita)*
bregeriana (walkeri)	*mexicana (isabella)*
casta (piperita)	*nebrites (erosa)*
comptonii (piperita)	*obvelata (annulus)*
contraria (friendii)	*pericalles (pulchella)*
dayritiana (luchuana)	*petitiana (pyrum)*
dissecta (piperita)	*raysummersi (hammondae)*
emblema (angustata)	*reticulifera (bicolor)*
episema (venusta)	*subteres (teres)*
euclia (bicolor)	*succincta (onyx)*
gambiensis (zonaria)	*summersi (pallidula)*
icterina (moneta)	*titan (carneola)*
leviathan (carneola)	*tortirostris (chinensis)*
waikikiensis (fimbriata)	

LITERATURE CITED

Allan, Joyce

1956. Cowry shells of world seas. Georgian House, Melbourne. i - x; pp. 1 - 170; plts. 1 - 15

Anonymous

1963. Personality of the month. Raymond H. Summers. Hawaiian Shell News **12** (1): 7 (November 1963)

Brand, D. J.

1964. *Notocypraea casta.* The Cowry **1** (6): 85 - 87 (18 January 1964)

Cate, Crawford Neill

1962. Comparison of two rare cowrie species (Gastropoda) The Veliger **5** (1): 6 - 14; plts. 1 - 4; 2 text figs. (1 July 1962)

1963. A new cowrie from west-central Philippines. The Veliger **5** (4): 140 - 143; plt. 15; 1 text fig. (1 Apr. 1963)

Cernohorsky, Walter Oliver

1963. Catalogue of living Cypraeidae. C. G. Smith, Frankfurt/Main; 24 unnumbered pages

1964 a. Note on *C. summersi.* The Cowry **1** (6): 81 - 82 (18 January 1964)

1964 b. The Cypraeidae of Fiji (Mollusca: Gastropoda). The Veliger **6** (4): 177 - 201; plts. 21 - 26; 1 Text fig.; 1 map (1 April 1964)

Cotton, Bernard Charles

1948. Southern Australian Gastropoda. Part III. Trans. Roy. Soc. South Austral. **72** (1): 30 - 32

Griffiths, R. John

1961. *Notocypraea* - the shells. The Cowry **1** (2): 26 - 30 [renumbered from 10 - 14 in **1** (3): 48] (April 1961)

1962. List of species. The Cowry **1** (3): 35 - 38 (1 February 1962)

1963. A note on *Cypraea casta.* The Cowry **1** (5): 67 - 68 (1 March 1963)

1964 a. Yet another note on *C. casta.* The Cowry **1** (6): 87 (18 January 1964)

1964 b. *C. hammondae.* The Cowry **1** (6): 88 - 89 (18 January 1964)

Schilder, Franz Alfred

1941. Verwandtschaft und Verbreitung der Cypraeacea. Arch. Molluskenk. **73** (2-3): 57 - 120; 2 plts.

1958. Über drei seltene Cypraeacea. Arch. Molluskenk. **87**: 81 - 87

1961 a. New cowries described since 1938. The Cowry **1** (2): 17 - 21 [renumbered from 1 - 5 in **1** (3): 48] (April 1961)

1961 b. Another statistical study in size of cowries. The Veliger **4** (2): 107 - 112 (1 October 1961)

1961 c. Nachträge zum Katalog der Cypraeacea von 1941. Arch. Molluskenk. **90**: 145 - 153

1962 a. Zur Kenntnis der Cypraeidae. 5. Eine neue Riesenform aus Ostafrika. Arch. Molluskenk. **91**: 207 - 212

1962 b. Note on *Bistolida luchuana* Kuroda. The Cowry **1** (3): 39 (1 February 1962)

1963 a. Further remarks on two rare cowrie species. The Veliger **5** (4): 125 - 128 (1 April 1963)

1963 b. Lumpers and splitters. The Veliger **6** (2): 104 - 110 (1 October 1963)

1963 c. Zur Kenntnis der Cypraeidae. 6. Über zwei seltene Arten aus Japan. Arch. Molluskenk. **92**: 123 - 130

1964 a. A further note on *N. casta.* The Cowry **1** (6): 83 - 84 (18 January 1964)

1964 b. Provisional classification of the genus *Notocypraea* Schilder, 1927. The Veliger **7** (1): 37 - 42 (1 July 1964)

1964 c. Zur Kenntnis der Cypraeidae. 7. Eine neue *Notadusta* aus Melanesien. Arch. Molluskenk. **93**: 141 - 144

Schilder, Franz Alfred, & Maria Schilder

1938. Prodrome of a monograph on living Cypraeidae. Proc. Malacol. Soc. London, **23** (3): 119 - 180; (1939) **23** (4): 181 - 231; 1 text fig.; 9 maps.

1940 a. Die Verbreitung und Häufigkeit der rezenten Cypraeidae. Arch. Molluskenk. **72** (2/3): 33 - 56

1940 b. Die Bestimmung der relativen Häufigkeit einer Art. Arch. Molluskenk. **72**: 160 - 169

1952. Ph. Dautzenberg's collection of Cypraeidae. Mém. Inst. Roy. Sci. Nat. Belgique (2) **45**: 1 - 243; 4 plts.

Schilder, Maria & Franz Alfred Schilder

1964. Maxima and minima in cowry shells. Hawaiian Shell News **12** (12): 6 - 8 (October 1964)

Schilder, Franz Alfred & Raymond H. Summers

1963. One more species of *Notocypraea.* The Cowry **1** (5): 65 - 66 (1 March 1963)

Steadman, W. R., & Bernard C. Cotton

1946. A key to the classification of the cowries (Cypraeidae). Records South Austr. Mus. **8**: 503 - 530; 6 plts.

Wagner, Robert J. L. & R. Tucker Abbott

1964. Standard catalog of shells. Van Nostrand, Princeton; ix + 190 pp.; illustr. (16 November 1964)

A New Cowrie Race from North West Australia

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(Plate 29; 6 Text figures)

In Cypraeidae, especially in Cypraeovulinae with a restricted range of distribution, many species show distinct subspecific differences between the populations inhabiting the North West coast of Australia and those living along the East coast of that continent. We recall the pairs of:

Western races	Eastern races
Erosaria cernica (Sowerby, 1870)	
viridicolor (Cate, 1962)	*tomlini* Schilder, 1930
Erronea subviridis (Reeve, 1835)	
dorsalis Schilder & Schilder, 1938	*subviridis* (Reeve, 1835)
Erronea cylindrica (Born, 1778)	
sowerbyana Schilder, 1932	*cylindrica* (Born, 1778)
Palmadusta lutea (Gmelin, 1791)	
lutea (Gmelin, 1791)	*humphreysi* (Gray, 1825)
Purpuradusta gracilis (Gaskoin, 1849)	
irescens (Sowerby, 1870)	*macula* (Angas, 1867)
Cribraria cribraria (Linnaeus, 1758)	
fallax (Smith, 1881)	*melwardi* (Iredale, 1930)

and several other species.

To these species we add *Purpuradusta hammondae* (Iredale, 1939, p. 312, plt. 28, figs. 19, 20 [adult holotype] and figs. 21, 22 [juvenile paratype]), the type locality of which is Clarence River in northern New South Wales. Its range extends from Woolgoolga to Clarence River, Moreton Bay, Stradbroke Island, Caloundra, Mooloolaba, Maroochydore, Gladstone and Tryon Island off Yeppoon, and has also been reported from Yirrkala in eastern Arnhem Land (Iredale, 1939, p. 313); it has been collected in North West Australia, viz. at Broome (Cate, 1964, p. 18), at Point Samson (near Roebourne) and in the Dampier Archipelago (Bezout Island, Delambre Island, Sholl Island).

The West Australian ("Dampierian") specimens differ from the typical East Australian ones at least statistically in several characters so that we propose to separate them as

Purpuradusta hammondae dampierensis Schilder & Cernohorsky, subsp. nov.

(Plate 29, Figures 1, 2; Text figure 1)

Shells smaller than the East Australian *Purpuradusta hammondae* (Iredale, 1939), much more slender, subpyriform (instead of rather ovate), with the anterior extremity attenuated, right side less margined, left side rather rounded, labial teeth less close as their relative number is smaller; dorsum greyish (instead of whitish) with the continuous true dorsal bands more accentuated while the transverse rows of square spots become obsolete, brown dorsal specks less close, dark lateral spots often sparse, base very pale brownish (instead of white).

The formula expressing the length (in mm), the relative breadth (in %of length), the absolute number of labial:columellar teeth (the left anterior terminal ridge excluded) and the closeness of the teeth (according to Schilder, 1958, pp. 77-80) is 13.0/58 16:16 *or* in the holotype in the British Museum, Natural History (No. 1964500), 12.1/59 18:16 *rs* in paratype 1 (coll. Schilder, No. 18197), and 11.8/60 16:13 *om* in the male paratype 2 (coll. Cernohorsky). These three type specimens were collected alive at Point Samson, West Australia, by D. Hurrell and L. J. Dorward in 1963. Other specimens studied by us came from Point Samson (coll. E. D. Harton), Delambre Island (coll. E. Fobes), and from

three islands in the Dampier Archipelago (coll. Ray Summers); the measurements published by CATE (1964, p. 18) also refer to *Purpuradusta hammondae dampierensis*, whereas there are no data about the shell from Yirrkala, Arnhem Land (IREDALE, 1939, p. 313).

There is also a close relationship between *Purpuradusta hammondae* (especially the West Australian *P. h. dampierensis*) and the Malayan *P. raysummersi* SCHILDER, 1960 (p. 190, plt. 15, fig. 5) which seems to be restricted to the Philippine Islands. Though GRIFFITHS (1964, p. 89) classified *P. hammondae* and *P. raysummersi* as distinct species, we now think the latter to be a third race of *P. hammondae* only: *P. raysummersi* is larger and more slender, and its teeth of both lips are finer, more close and more numerous: the average formula is (adult specimens only)

14	*P. hammondae dampierensis*	12.7/58 15:15 *np*
32	*P. hammondae hammondae*	13.8/61 17:15 *pp*
38	*P. hammondae raysummersi*	14.9/56 20:17 *rr*

Furthermore, *Purpuradusta hammondae raysummersi* differs from the other two races by the more saturate colour, the more accentuated dorsal zones, and the tips of the extremities which are brownish-purple instead of rosy.

The correlation between the length and relative breadth as well as that between the closeness of labial and columellar teeth has been shown in two diagrams, in which *Purpuradusta hammondae hammondae* is indicated by circles, *P. h. dampierensis* by crosses, and *P. h. raysummersi* by black dots (the squares indicate the mean or median of each character). In size *P. h. hammondae* is intermediate between the other two races, while in breadth it differs much from them (*P. h. dampierensis* and *P. h. raysummersi* follow the usual line of regression small/broad to large/slender, which can be observed in many cowrie species); in dentition *P. h. hammondae* is also intermediate between the other two races.

Extreme specimens without indication of habitat often cannot be identified exactly, as is usually the case with geographical races of cowries; the geographical distribution of the three subspecies, however, viz. the East Australian *Purpuradusta hammondae hammondae*, the West Australian *P. h. dampierensis* and the North Malayan *P. h. raysummersi* is well separable, as there are discontinuities in the range of the species *P. hammondae* in the Torres Straits and in southern Indonesia.

The species *Purpuradusta hammondae* can be easily separated from *P. gracilis* (GASKOIN, 1849) by the blackish-brown spire blotch and by the regular dorsal zones and square-spotted bands, while a real dorsal blotch is absent (only in a few specimens from Moreton Bay, leg. A. Schelechoff, the crowded dorsal specks begin to coalesce into a small central blotch); in the Australian races the outlets are rosy (but in some specimens of the East Australian *P. hammondae*, there is an accessory chestnut spot above the left part of the rosy anterior extremity).

The radula of paratype 2 of *Purpuradusta hammondae dampierensis* (text figure 1, median tooth 0.091 mm

Figure 1:
Purpuradusta hammondae dampierensis SCHILDER & CERNOHORSKY subspec. nov., male Paratype 2 from Point Samson

broad) seems to differ from that of a *P. h. hammondae* from Moreton Bay (text figure 2; leg. A. Schelechoff, coll.

Figure 2:
Purpuradusta hammondae hammondae (IREDALE) specimen from Moreton Bay

Explanation of Plate 29

Figure 1: *Purpuradusta hammondae dampierensis* SCHILDER & CERNOHORSKY, subsp. nov., Holotype (British Museum, Natural History); length 13.0 mm. Figure 2: *P. hammondae dampierensis*, Paratype 2 (coll. Cernohorsky); length 11.8 mm. Figure 3: Three specimens of *P. hammondae hammondae* (IREDALE) from Stradbroke Island (coll. Cernohorsky); length: 15.0 mm, 13.9 mm and 13.4 mm respectively. Figure 4: Two specimens of *P. hammondae raysummersi* SCHILDER, from Siasi Island (coll. Cernohorsky); length: 15.0 mm and 15.8 mm, respectively

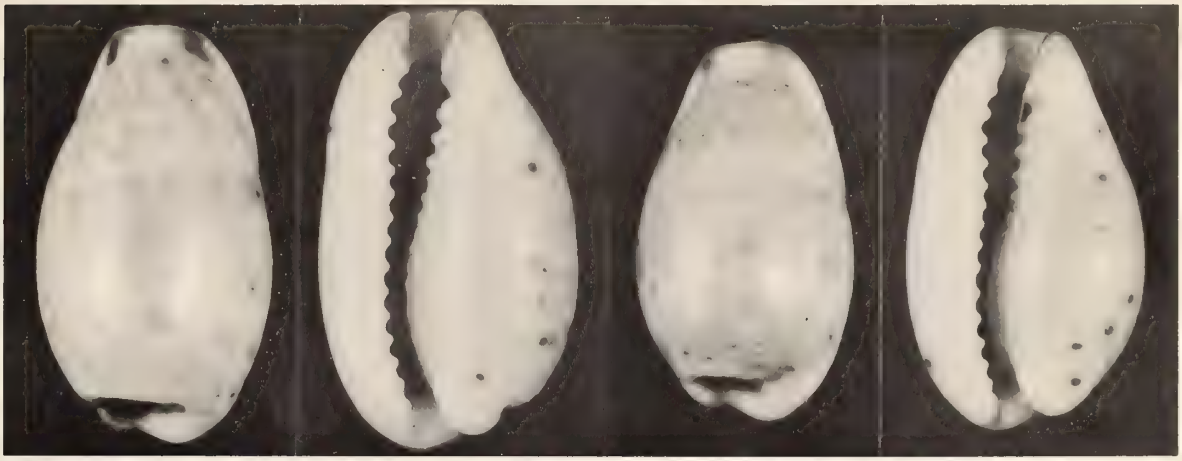

Figure 1 Figure 2

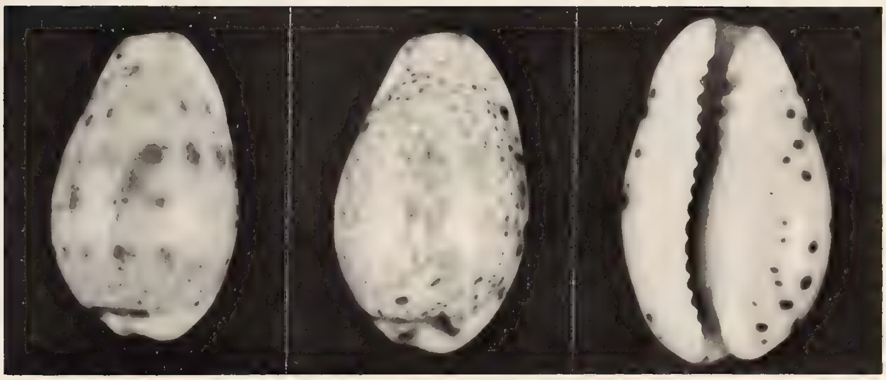

Figure 3

Figure 4

W. O. CERNOHORSKY *photo.*

Schilder No. 18389, shell 15.3 mm long, median tooth 0.097 mm broad) by the median and admedian teeth being elongate longitudinally, with the accessory lateral denticle less accentuated, and by the lateral teeth lacking the inner denticles. Such differences, however, occur also among *P. h. raysummersi* from Siasi Island: text figure 3 shows the radula of a specimen (coll. Summers, shell 12.3 mm long, median tooth 0.078 mm broad) which approaches *P. h. dampierensis,* whereas text figure 4 shows another specimen (coll. Schilder No. 11355, shell 15.7 mm long, median tooth 0.073 mm broad) which agrees with *P. h. hammondae*. Therefore we think these differences in radulae to be possibly sexual, but not racial.

Figure 3:
Purpuradusta hammondae raysummersi (Schilder)
small specimen from Siasi Island

Figure 4:
Purpuradusta hammondae raysummersi (Schilder)
large specimen from Siasi Island

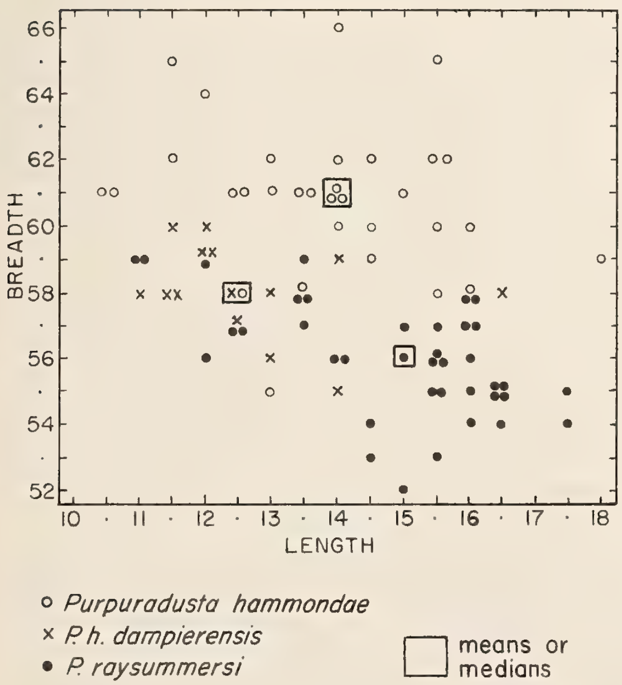

Figure 5:
Diagram showing the correlation between length and relative breadth of *Purpuradusta hammondae* (Iredale)

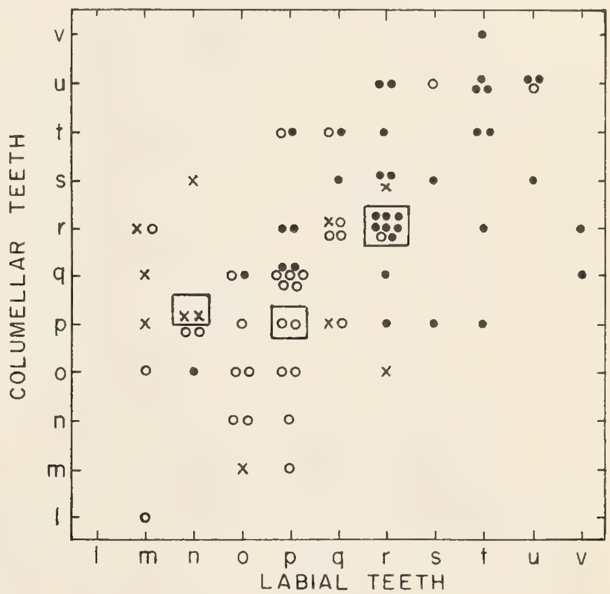

Figure 6:
Diagram showing the correlation between the closeness of labial and columellar teeth of *Purpuradusta hammondae* (Iredale)

LITERATURE CITED

Cate, Crawford Neill

1964. Western Australian cowries. The Veliger 7 (1): 7-28; plt. 5; 1 map (1 July 1964)

Griffiths, R. John

1964. *C. hammondae.* The Cowry 1 (6): 88-89 (18 January 1964)

Iredale, Tom

1939. Australian cowries: Part II. Austral. Zoologist 9 (3): 297-323; plts. 27-29

Schilder, Franz Alfred

1958. Die Bezeichnung der Zahndichte der Cypraeacea. Arch. Mollusk. 87 (1-3): 77-80.

1960. Zur Kenntnis der Cypraeidae. Arch. Molluskenk. 89 (4/6): 185-192; plts. 14-15

Predator-Prey Reactions Between Two Marine Prosobranch Gastropods

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INTRODUCTION

Specific behavior patterns elicited from many mollusks by the touch of certain starfish or extracts from them have been demonstrated in experiments performed under laboratory conditions (Bullock, 1953; Margolin, 1964a). These experiments indicate that such actions could function in nature as effective escape reactions to potential predators. Such escape reactions may be demonstrated with many prosobranch gastropods, particularly intertidal forms such as limpets and turban snails. Escape reactions are not restricted to gastropods among the mollusca but are also shown by pectens and cockles (Ray, 1959) to the presence of certain starfish.

While the experimental evidence of the effectiveness of these reactions is convincing, there is a lack of information on the spontaneous occurrence of these reactions in predator-prey confrontations under entirely natural conditions. Margolin, 1964b, found that the escape response shown by *Acmaea* to starfish did not prevent their eventual capture in an aquarium and concluded that his results may indicate a lack of survival value for the flight reaction, at least in the laboratory. Feder, 1959, on the other hand, found that gastropods were not eaten in the field by *Pisaster ochraceus* in proportion to their numbers and concluded that the known escape responses of *Acmaea* spp., *Tegula* spp., and *Haliotis* spp. may be protective to the species. Field observations on spontaneous prey-predator contacts would make possible an evaluation of the effectiveness of these mechanisms in nature and their importance as selective factors in the evolution of the mollusks involved.

Most predatory marine gastropods feed upon sedentary prey organisms such as bivalves, barnacles, coelenterates, tunicates, and worms. Consequently, the more complicated aspects of their feeding behavior usually involve the mechanisms used in detecting food, holding and opening the shells of prey or boring into them, rather than the pursuit and capture of prey. Notable exceptions are the stalking and capture of fishes by *Conus* spp. observed by Kohn, 1961, and the trailing of prey species by *Navanax inermis* observed by Paine, 1963. Naticids are common predatory marine gastropods of soft bottoms which feed principally upon clams, but also upon other gastropods. Information on their method of feeding upon clams has been summarized by Fretter & Graham, 1962. Clams are held in the extensive foot of the naticid while a hole is bored in the shell. Capture and feeding take place below the surface of the bottom.

An example of active pursuit by a naticid of a gastropod prey species, together with an escape reaction by the prey was observed under field conditions on the Pacific coast of Costa Rica. Predator induced escape reactions involving two gastropod species appear to have been observed in the field and described briefly only once before (Clark, 1958), and the observations recorded here provide some information on how naticids capture other, active gastropods in nature.

The field observations were made on an intertidal flat of sandy mud near the town of Golfito, Costa Rica, on the Golfo Dulce (83° 10′ W, 8° 38′ N). According to Keen, 1960, both species involved are common on intertidal mud flats from the Gulf of California to Ecuador, which should permit detailed anlysis of their behavior later. The predator species involved is a variant of *Natica (Natica) chemnitzii* Pfeiffer, 1840, called *Natica unifasciata,* which is characterized by one white band on the upper part of the whorls of the brownish shell. There are unresolved taxonomic difficulties with this species complex. Some of the specimens used have been deposited in the collections of the California Academy of Sciences so that the taxonomic status of the *Natica* species involved may be verified at a later time. The prey snail is readily identified as *Nassarius (Arcularia) luteostoma* (Broderip & Sowerby, 1829).

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PREY CAPTURED BY *Natica unifasciata*

Natica unifasciata is abundant on the mud flats at Golfito, crawling rapidly about on the surface at low tide. The gross morphology of this naticid is typical of the family. There is an extensive, wide anteriorly extended portion of the foot (the propodium) and a large, flat ventral mesopodium which is expanded posteriorly into a thin, widened posteriorly trailing portion. Many *N. unifasciata* were found crawling about with a clam, covered with thick sticky material, firmly stuck to the underside of the posterior foot lobe which covered it like a sucker. The largest snails found had shell diameters of about 2 cm and a total length of the body when extended of about 5 cm. Most of the clams being carried about were small in relation to the snail and scarcely protruded from beneath the posterior foot lobe. However, some were dragging clams of about 4 cm shell length, much larger than the posterior foot lobe; thus demonstrating the effectiveness of the hold exerted on the prey by the bottom surface of the foot.

Natica unifasciata were also found carrying *Nassarius luteostoma*. The nassarid is small enough to be completely covered by the foot. It is held in an inpocketing of the bottom surface and is thus virtually entirely enveloped. This produces a lump in the dorsal surface of the posterior foot lobe, permitting those *Natica* carrying nassarids to be identified and followed. *Natica* carrying either a clam or *Nassarius* could be followed as they crawled about the surface for a distance of one or two feet, after which they pushed into the mud and slowly burrowed from sight, carrying the captured prey. If they are disturbed while on the surface, they will continue to crawl about, but buried *Natica* immediately re-burrowed when uncovered. Capture and carrying of the prey across the surface appears to be a peculiarity of this naticid, but it burrows with its prey, and like other members of the family, feeds upon it below the surface.

The method of capture of the prey snail and the manner in which prey are attached to the foot were also observed in the field as they occurred spontaneously. *Natica unifasciata* crawls rapidly about the mud flat, apparently without direction. If the prey snail was contacted directly by the anterior foot lobe, capture was immediate. When the trail left in the mud by a crawling *Nassarius* was crossed, the *Natica* immediately began to follow it and overtook the slower crawling nassarid if the proper direction was chosen. This was observed several times as *Natica* crossed the trails of nassarids about 6 inches away. The details of escape reactions of the prey upon contact are described below. When contact is made, the nassarid becomes very active and moves rapidly and erratically. *Natica unifasciata* is able to sense the changes in direction of the nassarid trail and accurately pursues them. Usually several attempts at capture were tried before a successful hold was obtained upon the prey. Capture is effected by lifting the wide propodium above the surface of the mud with the thin, flat edges extended laterally, and bringing it down rapidly over the small prey snail. If the prey is successfully covered, the front edge of the propodium is curved down and rolled partially around the struggling nassarid. As the prey is slowly enrolled in the propodium, the *Natica* falls on its side as the more posterior portions of the foot are brought ventral and forward, free of the substrate. The head area is brought ventral and posterior, meeting the posterior portion of the foot curving forward. The prey is thus entirely surrounded by the foot. The long axis of the shell of the nassarid is held across the width of the anterior part of the foot and is slowly rotated as it is moved posteriorly. As it is rolled by the propodium, it is covered with a thick, sticky mucus. Nassarids examined at this point had stopped struggling and were withdrawn into their shells. The prey is slowly transferred poteriorly to the apron-like posterior foot lobe which holds it in a sucker-like fashion. As the prey reaches the posterior end of the foot, the *Natica* rights itself with the propodium and begins to crawl away, carrying the prey. Clams being carried were also found completely covered with this thick mucus, which is apparently important in both subduing the more active prey and maintaining the hold by the posterior foot. Capture of a second prey individual was not observed to occur naturally. All *Natica* carrying prey that were followed eventually burrowed below the surface.

In the field *Natica* pursued *Nassarius* placed in their immediate vicinity. Other snails found on the mud flat and placed in contact with the *Natica* were not taken. Clams removed from the foot lobe and left next to the *Natica* were re-secured by the propodium and re-attached to the posterior foot lobe.

Specimens of *Natica, Nassarius,* and several other species of prosobranchs from the mud flat were placed together in bowls of sea water. The *Natica* continued to follow *Nassarius* about, but showed no reactions to the other species of snails when they touched them, even when left together with them overnight. A variety of sizes including individuals of the size of the *Nassarius* were used in this experiment. *Natica unifasciata* does not react to shells of *Nassarius luteostoma* occupied by small hermit crabs.

ESCAPE REACTIONS OF *Nassarius luteostoma*

The behavior of *Nassarius luteostoma* when confronted with *Natica unifasciata* was observed as spontaneous contacts were made by undisturbed animals in the field and also by placing the species together both on the mud flat and in bowls of sea water. The reactions are the same in all cases.

It is evident from the precise directionality of its pursuit that the *Natica* can sense some substance left by the nassarid in its trail across the mud. The nassarid also appears to be able to detect the predator by chemosensory means. *Nassarius* placed in small puddles on the beach containing several *Natica* very rapidly crawled out and away. When the two species are placed together in bowls, the nassarids slowly crawl about at random and occasionally toward a *Natica*. However, if they approach a *Natica* within about $1\frac{1}{2}$ to 2 cm, they will turn and crawl rapidly away.

If *Natica* is picked up, it will slowly withdraw into the shell, releasing a little water from the pallial cavity and the foot surface as it does so. This fluid was collected with a pipette and released near quiet nassarids in a bowl of sea water. The fluid invariably elicited the entire series of escape reactions described in detail below, without any actual contact with the body of a *Natica*. A flow of ordinary sea water is without effect.

These observations establish that the *Nassarius* can sense the predator a short distance away by some chemosensory means and will then begin to crawl away rapidly. Closer contact with a *Natica* produces more active behavior similar to the escape reactions shown by other prosobranchs to starfishes.

If any of the parts of the body of *Nassarius luteostoma* come into contact with those of *Natica*, the *Nassarius* immediately begins a series of rapid actions. In nature, the course of these actions proceeds as follows. Upon contact, the nassarid extends the foot and head from the shell maximally and usually falls upon its side as the shell is swung from side to side. The foot assumes an elongate, slender shape and the head and foot region thrashes about rapidly. The elongated foot acts as a lever and its violent jerks from side to side move the snail erratically, but rapidly, over a distance of about three inches. If this violent leaping removes the nassarid from the vicinity of the *Natica*, it then rights itself and crawls rapidly away, with the shell held high over the foot. After crawling about six inches, it slows and lowering the shell, resumes its slower undisturbed crawling. One contact with *Natica* will induce very active escape behavior of about 30 seconds duration.

Efforts made to demonstrate fatigue of the escape reaction were not successful. Nassarids were touched against *Natica* held in bowls with them. The entire sequence of actions was induced repeatedly, without failure, even if repeated at intervals of one minute, as soon as the nassarid stopped the thrashing action induced by earlier contacts. Gradual fatigue of the response of limpets to starfishes by repeated frequent contact was demonstrated by Margolin, 1964a. Individuals of *Nassarius luteostoma* continued to react violently as long as they were held against the *Natica*.

DISCUSSION AND CONCLUSIONS

Natica unifasciata carries both clam and snail prey for some distance about on the surface before feeding and in this behavior differs from related species which capture and feed on clams below the surface. Other naticids also cover clam prey with mucus and are able to drag the prey with the foot down below the surface, but apparently not for any distance across the surface (Fretter & Graham, 1962). There is no comparable information available on the method used by other Naticidae to capture gastropod prey. The carrying of the snail prey by *Natica unifasciata* is related to its pursuit and capture of active *Nassarius luteostoma* on the surface of the mud flat, and its extension to carrying clams, which might be taken under the surface, is probably secondary. The observations indicate that the mechanism used by *Natica* to sense its prey is sufficiently sensitive to permit the detection and pursuit of prey capable of active avoidance. It is probable that the capture of gastropods by other members of the Naticidae is different from the slow means which they use on clams.

The observations made under natural field conditions demonstrate that *Nassarius luteostoma* possesses an escape reaction mechanism toward its predator, *Natica unifasciata*, which can allow the *Nassarius* to successfully escape attack by its predator. However, the initial violent movements of the reaction do not always move the *Nassarius* away from the *Natica*, and thus may fail to prevent capture. Such failure was observed directly in the field and is also demonstrated by the number of *Natica* found carrying captured *Nassarius*. It may be concluded that escape reactions in gastropods produce some success under natural conditions and are thus of selective importance. They do not, however, insure individual survival.

Escape reactions, mediated by chemoreception, are known for other species of *Nassarius*, which, however, respond to the presence of or extracts from starfishes predatory on the *Nassarius* rather than to another snail.

The literature on the reaction of these *Nassarius* species has recently been summarized by both KOHN (1961) and FRETTER & GRAHAM (1962). The use of the foot in the movements involved in the reaction is essentially the same as in *N. luteostoma,* even though induced by very different predators. The presence in *N. luteostoma* of a specific escape reaction to a predatory gastropod indicates that these reactions in prosobranchs are developed in response to predators which are relatively slow moving and not exclusively to carnivorous starfish. The sensory basis in both cases is chemosensory detection of material released by the predator.

Flight reactions of normally sedentary animals would not be expected to be an efficient response to fast moving predators such as fishes and indeed, only slow moving predators are involved in the known flight reactions of marine invertebrates. This is the most important common characteristic of the reactions between otherwise diverse predator-prey pairs such as *Aeolidia/Stomphia* (ROBSON, 1963), *Natica/Nassarius* and *Pisaster brevispinus/Dendraster excentricus* (MACGINITIE & MACGINITIE, 1949). REESE (1964), in a general review of the behavior of marine animals, also concluded on different grounds that convergence of adaptive behavior patterns in species confronted with similar problems is a general phenomenon.

Reactions of herbivorous gastropods to predatory snails were described for a number of species by CLARK (1958). One of these reactions was observed as it occurred spontaneously in the field and bears some resemblance to the *Natica/Nassarius* reaction. CLARK observed that when the thaisid whelk *Lepsia haustrum* touched the trochid *Melagraphia aethiops* the latter exhibited rapid reactions which involved violent swinging of the body in a manner similar to that described here for *Nassarius.* However, contact between the two snails was apparently random and the predatory *Lepsia* was not observed to pursue the trochid or feed upon it.

It was not clear whether the responses shown by the other species studied by CLARK in the laboratory were specific responses to a snail predatory on these species, and operative under natural conditions or whether the responses to the carnivorous snails were fortuitous and not of survival importance in nature. The species studied by CLARK also showed escape responses to carnivorous starfishes, and he found no correlation between the co-occurrence of the snail species and reactions between them. Some pairs of snail species reacted which probably never meet in nature. In other cases (MARGOLIN, 1964a) escape reactions have been demonstrated experimentally between snails and starfishes which either never take the reacting species naturally or which do not occur in the same habitat. ROBSON (1963) showed that an escape reaction of the anemone *Stomphia coccinea* to its predator, *Aeolidia papillosa* is also evoked by certain starfishes which are not predators of the anemone, but which also produce a substance which will induce the reaction. In these cases, the reactions seem to have been developed as a specific adaptive response in one prey-predator relationship, and are operative in response to species which are not normal predators because of chance production by these species of substances which will elicit the response. No such ambiguity is present in the relation between *Natica* and *Nassarius* described here. Observation in the natural habitat demonstrated that a prey-predator relation exists between the two species and that the reaction can allow successful escape from the attacking predator and is thus adaptive. The ecological significance of the many flight reactions of marine invertebrates demonstrated under laboratory conditions cannot be evaluated until these observations are extended to observations of the species involved under entirely natural field conditions.

An instance of an apparent escape reaction shown by one snail to another carnivorous snail species was mentioned by PETERS (1964). In this case *Littorina planaxis* showed an escape flight from the carnivorous *Acanthina spirata* in the laboratory and also to a substance released into the water by the predator, as does *Nassarius* to the fluid from *Natica. Acanthina* and *Littorina* are known to occur in the same general habitat on the Pacific coast of North America, but a prey-predator relationship under natural conditions has not been demonstrated.

Similarly, ROBERTSON (1961) found that in an aquarium, *Strombus gigas, S. costatus* and *S. raninus* leaped violently away from the carnivorous snail, *Fasciolaria tulipa.* The escape reaction was not observed under natural conditions. However, in this case a prey-predator relation was established by field observation. ROBERTSON frequently found *F. tulipa* feeding on *S. gigas* and considered it to be the principal predator of *Strombus* at Bimini. It would appear that in this case the escape reaction is only partially effective against attack by the predator, as it is in the *Natica-Nassarius* case.

SUMMARY

Natica chemnitzii, a predator of both clams and *Nassarius luteostoma* on the mud flats at Golfito, Costa Rica, carries its captured prey across the surface of the flat by holding them with the posterior lobe of the foot.

Natica can detect and follow the trails of *Nassarius* across the mud. It captures the snail by throwing the wide anterior end of the foot over the prey, rolling it in a sticky mucus and then holding it securely by the sucker-like action of the posterior foot lobe.

Nassarius luteostoma can detect the presence of *Natica* through the water at a short distance and exhibits specific escape reactions to the presence or touch of *Natica*. Under natural conditions these quick actions often but not invariably allow the *Nassarius* to escape the pursuing predator.

Note added in proof:

YARNALL (1964) has recently investigated the response of *Tegula funebralis* to *Acanthina spirata* and *Thais emarginata,* both carnivorous prosobranchs from the same general habitat as the *Tegula*. The behavioral response of *T. funebralis* to pieces of the foot of these carnivores was considered essentially the same as the known escape reaction of *Tegula* spp. to starfish normally predatory on *Tegula*. The exact nature and function of this response, its spontaneous occurrence in the habitat and the existence of a true predator-prey relationship were not sufficiently established to make possible a comparison with the *Natica-Nassarius* interaction and others mentioned here.

(JJG - 21 Dec. 1964)

LITERATURE CITED

BULLOCK, THEODORE HOLMES

1953. Predator recognition and escape responses of some intertidal gastropods in the presence of starfish. Behaviour 5 (2): 130 - 140

CLARK, W. C.

1958. Escape responses of herbivorous gastropods. Nature 181 (4602): 137 - 138

FEDER, H. M.

1959. The food of the starfish, *Pisaster ochraceus,* along the California coast. Ecology 40 (4): 721 - 724

FRETTER, VERA, & ALASTAIR GRAHAM

1962. British prosobranch molluscs, their functional anatomy and ecology. London, Ray Soc. xvi + 755 pp.; 316 figs.

KEEN, A. MYRA

1958. Sea shells of tropical west America; marine mollusks from Lower California to Colombia. Stanford Univ. Press, xi + 624 pp.; illus. Stanford, Calif.

KOHN, ALAN J.

1956. Piscivorous gastropods of the genus *Conus.* Proc. Nat. Acad. Sci. 42: 168 - 171.

1961. Chemoreception in gastropod molluscs. Am. Zool. 1: 291 - 308.

MACGINITIE, G. E., & NETTIE MACGINITIE

1949. Natural history of marine animals. McGraw-Hill Book Co., Inc. New York. pp. 1 - 473; 282 text figs.

MARGOLIN, A. S.

1964 a. The mantle response of *Diodora aspera.* Animal Behavior 12 (1): 187 - 194

1964 b. A running response of *Acmaea* to seastars. Ecology 45 (1): 191 - 193

PAINE, ROBERT T.

1963. Food recognition and predation on opisthobranchs by *Navanax inermis* (Gastropoda: Opisthobranchia). The Veliger 6(1): 1–9; plt. 1; 1 text fig. (1 July 1963)

PETERS, RONALD L.

1964. Function of the cephalic tentacles in *Littorina planaxis* Philippi (Gastropoda: Prosobranchiata). The Veliger 7(2): 143–148; 10 textfigures. (1 October 1964)

RAY, D. L.

1959. Trends in marine biology. pp. 1 - 8 in I. PRATT & J. E. MCCAULEY, eds. Marine Biology, 20th Ann. Biol. Colloq., Oregon State College, Corvallis, Ore.

REESE, E. S.

1964. Ethology and marine zoology, pp. 455 - 488 in H. BARNES, ed., Oceanogr. Mar. Biol. Ann. Rev., vol. 2. Allen and Unwin, London.

ROBERTSON, ROBERT

1961. The feeding of *Strombus* and related herbivorous marine gastropods. Notulae Naturae Acad. Nat. Sci. Phila.; no. 343; 9 pp.

ROBSON, E. A.

1963. The swimming behavior of the sea anemone *Stomphia coccinea.* Proc. XVI Internat. Congr. Zool., vol. 1: 61.

YARNALL, JOHN L.

1964. The responses of *Tegula funebralis* to starfishes and predatory snails (Mollusca: Gastropoda). The Veliger 6, Supplement: 56 - 58 (15 November 1964)

Note on a Range Extension and Observations of Spawning in *Tegula*, a Gastropod

BY

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THE NORTHERNMOST RECORD for *Tegula brunnea* heretofore has been from Mendocino County, California. However, I collected *T. brunnea* from Cape Arago, Oregon, Lat. 43° 18′ 10″ N, Long. 124° 20′ W, in the summers of 1960, 1963 and 1964. It seems to be a regular inhabitant of the outer intertidal zone there. In 1960, it was collected at Middle Cove of Cape Arago and in the two later years at North Cove, which is 2° 52′ further north than the former California record; here it is usually associated with *T. pulligo* in the *Macrocystis* area. KEEN & DOTY (1942) record only two species from this area; they are *T. funebralis* and *T. pulligo*. The known range for *T. brunnea* is now from Coos Bay, Oregon south to Santa Barbara, California.

The characteristics of *Tegula brunnea* in Oregon are: shell with umbilicus closed; shell either gray above with orange or red-brown body whorl or totally orange or red-brown; no teeth on columella evident; foot black with a prominent orange or red-brown border, mantle lobes near head (collar) black but with yellow borders. Epipodia wholly black. According to Dr. Rudolf Stohler (*in litt.*, 1964), these northern forms appear larger than similar Californian material.

Body coloration coupled with shell characteristics seems to afford a good guide for separating the Oregon species of *Tegula*. A short key to the known Oregon species is offered below.

Key to the Oregon Species of *Tegula*

1. Umbilicus covered by a callus, closed; epipodia of uniform color throughout 2
— Umbilicus open; epipodia lighter near base .... *Tegula pulligo* (GMELIN, 1784)
2. Shell color purplish or black; tooth evident on columella ...... *Tegula funebralis* (A. ADAMS, 1855)
— Shell greyish above, with red-brown to orange body whorl or entirely brown; no teeth on columella evident .... *Tegula brunnea* (PHILIPPI, 1848)

Tegula funebralis differs from *T. pulligo* in that the tentacles, head, upper portion of the foot and the epipodia as well as the collar or mantle lobes are wholly black. In *T. pulligo* the head is black dorsally, epipodia light colored at bases; antennae black, foot black with lavender-purple blotched or wine-colored to red-brown border; mantle lobes (collar) above head pinkish with yellow borders. Additionally, the shell color of *T. pulligo* is gray on top or with light colored blotches apically; body whorl with thin yellow or red-orange bands; sometimes entire shell magenta in color.

On August 8, 1964, several specimens each of both *Tegula brunnea* and *T. pulligo* were collected in the outer *Macrocystis* area of North Cove, Cape Arago, Oregon. They were placed in aquaria with running sea water at the Oregon Institute of Marine Biology, Charleston, Oregon; the water temperature was maintained at 15° to 16° C. The next night, alerted by the cloudiness of the water in the tank, I noted that one of the *T. brunnea* was discharging puffs of white sperm. Further observation revealed that female *T. brunnea* were laying eggs, bright grass-green in color. These eggs seemed to cover the body whorl in a single sheet as the snail held on to the side of the aquarium. After a time these eggs dropped off and fell to the bottom of the tank, which by this time was covered by large masses of the green eggs. At no time did the males appear to be attracted to the females, but they remained at a distance of from five to six inches. However, the possibility remains that one may stimulate spawning in the other. No egg capsules were built, the gametes being shed directly into the immediate environment.

Gametes were removed separately and fertilization was attempted. Upon fertilization most of the eggs appeared to have a fertilization membrane and several turned light green (moss-green) in color. Most of the zygotes attained the two-cell stage after about 50 minutes. Development continued until the 16-cell stage and then stopped. No later stages were found.

In speaking of *Tegula funebralis,* Dr. Peter Frank (*in litt.*, 1964), says that on August 13, 1964, three females of this species were observed with eggs within the shell when they retracted the foot upon being picked up. Many eggs were noted in the immediate vicinity. One of the snails was collected and its eggs were watched, in the

laboratory at Charleston; most did not cleave, only a few developed to the 4-cell stage or to subsequent stages. The three snails in question were found during low tide at about the plus 3.5 foot level.

These two observations, both made in August, appear to be the only recorded cases of spawning noted in these common snails.

LITERATURE CITED

KEEN, A. MYRA & CHARLOTTE L. DOTY

1942. An annotated check list of the gastropods of Cape Arago, Oregon. Oregon State Monogr. 3. Corvallis, Oregon.

Three Dimensional Reconstructions of the Nests of *Helix aspersa*

(Mollusca : Gastropoda : Pulmonata)

BY

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(Plate 30)

THE GROSS ASPECTS of the reproductive process in *Helix aspersa* have been reported at some length. The courtship process was described in detail by TRYON (1882), while other reports have dealt with the copulatory act, oviposition, hatching, and movement out of the nest (BASINGER, 1931; INGRAM, 1946 and 1947; HERZBERG & HERZBERG, 1962). In addition to the above factors which contribute to the total picture of reproductive behavior in this animal there must be added nest building, also a reproductive trait. A search of the literature failed to reveal any description of the actual three-dimensional structure of the nest in the ground in which this animal deposits its eggs. This experiment was designed to determine the nest structure of *Helix aspersa*.

MATERIALS AND METHODS

Twenty pairs of snails were placed separately in quart glass jars with aluminum screening covers. To permit clear observation of oviposition the bottom of each jar had moist soil about 5 cm in depth. It had earlier been determined that this amount of soil permitted observation of oviposition (HERZBERG & HERZBERG, 1962).

The animals were observed several times daily through the sides or bottom of the jars until they were found actually depositing eggs. When such animals were found they were disturbed by tapping with a pencil on their shells, followed by a slow lifting of the shell away from the soil. As the animal ceased oviposition and withdrew its body from the soil and toward the shell, it was further lifted out of the nest until the body was entirely freed. When conducted with much care, this procedure permitted removal of the animal without any visible distortion of the nest, thus leaving the nest cavity open with eggs visible at its bottom. Into the nest opening a loose mixture of plaster of Paris was poured, and gently vibrated into the nest opening until it overflowed the top, and then left to dry. After drying, the hard plaster mass was withdrawn from the soil and the particles of soil

Explanation of Plate 30

Figures 1 a, b, c: Three views of the plaster of Paris models of the blunt thumb-shaped nest of *Helix aspersa*.
Figures 2 a, b, c: Three views of the plaster of Paris models of the nest of *Helix aspersa* showing the long neck and the rounded bottom.

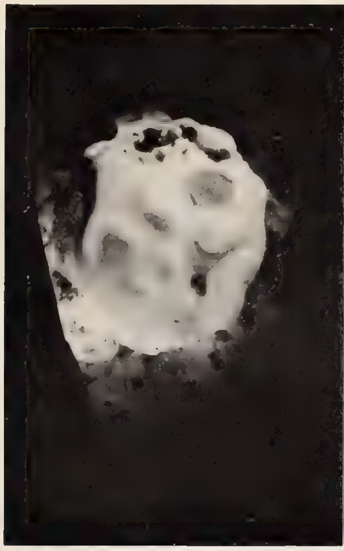
Figure 1 a


Figure 1 b


Figure 1 c


Figure 2 a


Figure 2 c


Figure 2 b

adhering to the plaster were removed by washing with water, thus leaving a plaster model with the eggs attached to its lowest portion. The eggs were painted with a very thin mix of plaster to preserve their outward shapes. Twenty-seven such models were poured. The remaining animals either failed to deposit eggs, or the deposited eggs were in a position where they could not be seen.

RESULTS

It was found that the nests of *Helix aspersa* were of two types. The models from the first type revealed that the animal's entire body occupied the nest space. This resulted in a blunt thumb-shaped nest with a rounded bottom, in which were seen the eggs deposited (Plate 30, Figure 1). The second type had a rounded bottom which was joined to the top of the nest by a relatively thin neck. The eggs were found in the rounded bottom portion of the nest. In this type it appeared as though the animal had extended its head downward, and did not expand its body during oviposition (Plate 30, Figure 2). Twelve nests fell into the first category and 15 were clearly of the second type.

SUMMARY

Three-dimensional plaster of Paris reconstructions of the nests of *Helix aspersa* were made and from this population two types of nests were apparent. In one type the bottom of the nest was joined to the top by a long thin neck, while in the other the nest was blunt throughout.

ACKNOWLEDGMENT

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LITERATURE CITED

Basinger, A. J.

1931. The European brown snail in California. Rep. Calif. Agric. Exper. Sta. Bull. 515; 20 pp. Univ. Calif. Berkeley.

Ingram, William Marcus

1946. The European brown snail in Oakland, California. Bull. So. Calif. Acad. Sci. 45: 152 - 159

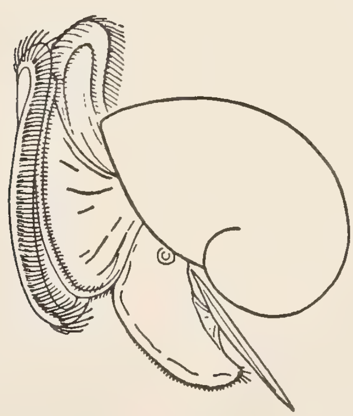
1947. Egg laying of the European brown snail in terraria. Bull. So. Calif. Acad. Sci. 46: 55 - 56

Herzberg, Fred & Anne Herzberg

1962. Observations on reproduction in *Helix aspersa*. Amer. Midland Naturalist 68: 297 - 306

Tryon, George Washington, Jr.

1882. Structural and systematic conchology. Vol. 1, Acad Nat. Sci. Phila.; 312 pp.



A Statistical Study in Fossil Cowries

BY

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Heilprin (1887, p. 86) established the monotypic genus *Siphocypraea* as the type species *Cypraea (Siphocypraea) problematica* Heilprin (*ibid.*, p. 87, pl. 4, fig. 12) differs from all fossil and living cowries by the curious posterior outlet which turns to the right so that its top opens towards the base (the name *Siphocypraea* is deplorable because its peculiarity consists in the posterior outlet and not in the quite normal anterior one, from which the animal's sipho protrudes). The species was said to be common in the Pliocene ("Floridian") beds at Fort Thompson, Caloosahatchee River, south western Florida.

Though the characters of the posterior outlet of *Siphocypraea problematica* are unique, Heilprin (*l. c.*, p. 87) compared it with *Cypraea carolinensis* Conrad (1841, p. 346, pl. 2, fig. 6) and Dall (1890, p. 167) with the living *Cypraea mus* Linnaeus, 1758. Schilder (1926, p. 367) recognized that *Siphocypraea problematica* is an "abnormal descendant" of *Cypraea carolinensis* and adopted the generic name *Siphocypraea* in all subsequent papers (1932, p. 119; 1941, p. 82) to designate the group of cowries which includes, besides the two species named above, also *S. henekeni* (Sowerby, 1849) and its American allies including the only Recent survivor *S. mus* from the north coast of Colombia and Venezuela.

Nevertheless, Gardner (1948, p. 213) established a "section" AKLEISTOSTOMA with *carolinensis* as type species on account of the weak columellar teeth and the absence of the "curious hook shaped opening" of *problematica;* Gardner observed that the tendency of columellar teeth to become obsolete also occurs in the Recent *S. mus.* Moreover, Woodring (1957, p. 88) established the subgeneric name *Muracypraea* with the just mentioned *mus* as type species, including also its Tertiary allies *henekeni*, etc.

In a recent paper, however, Olsson & Petit (1964, pp. 556 - 560, pl. 83) have demonstrated that there is a gradual evolution in development of the posterior outlet from the late Miocene *Siphocypraea carolinensis carolinensis* (Conrad, 1841) (Duplin beds of North Carolina) over *S. carolinensis floridana* (Mansfield, 1931) and two new subspecies of *S. carolinensis,* viz. *S. c. hughesi* and *S. c. transitoria* (all three from Upper Miocene Pinecrest beds of Florida) to *S. problematica* (Heilprin) (overlying Pliocene Caloosahatchee marls of Florida).

In 1963 and 1964 I received as gift from Mrs. J. W. Donovan (Palm Beach, Florida) many Neogene cowries from Florida, true *Siphocypraea problematica* as well as specimens which evidently are intermediate between *S. problematica* and the less singular species of *Siphocypraea,* especially *S. carolinensis.* I prepared a statistical paper and intended to name the connecting link (see Donovan 1963), but I postponed to publish the paper when I learned that Dr. A. A. Olsson had a paper on this subject in press, naming the intermediates *hughesi* and *transitoria.* As this paper is now published (Olsson & Petit, 1964), I should like to integrate it with my statistical research. The examined specimens are not very numerous if compared with the several hundred *Siphocypraea* preserved in American collections. Nevertheless, they seem sufficient to demonstrate my methods of investigating such a problem of gradual evolution.

In this paper I have restricted the study to the geologically younger members of the non-tuberculate branch of *Siphocypraea,* viz. the species *S. carolinensis* and *S. problematica.* The total range of variation in each essential character has been divided into six equal classes, numbered from 1 to 6, so that the extreme development in *S. carolinensis* is called 1, the other extreme occurring in *S. problematica* is called 6. The five chief characters are:

a) the length of the shell (measured in tenths of a mm);
b) the relative breadth (expressed in percent of the length);
c) the average closeness of teeth on both lips (classified by letters according to Schilder, 1958; the formula of labial : columellar teeth *il* becomes *k,* as well as the formula *li, hm, mh,* etc., while the mean of *kl, im,* etc. becomes *k*.5);
d) the width of the aperture in its central part (varying from the very broad aperture in *S. carolinensis* to the narrow one in *S. problematica*);
e) the turning of the posterior outlet to right (characterized by the flattened terminal part of the canal which tends towards the dorsum in *S. carolinensis*

but almost towards the base in *S. problematica*, and by the upper part of its right wall which, when seen from behind, is about vertical or even bent to the left in *S. carolinensis* as it is in most cowries, but becomes about horizontal in *S. transitoria* and invertedly vertical in extreme *S. problematica*: therefore one can classify the outlet by the turning of the top of its right wall from 0° to almost 180°, i. e. through two right angles).

The six classes have been defined as follows (the quoted figures illustrating the aperture and the posterior outlet refer to Olsson & Petit, 1964, pl. 83):

class	1	2	3	4	5	6
length (mm)	27 - 35	35 - 45	45 - 55	55 - 65	65 - 75	75 - 81
breadth (%)	69 - 73	66 - 68	63 - 65	60 - 62	57 - 59	53 - 56
teeth	g.5 - h.5	i - k	k.5 - 1.5	m - n	n.5 - o.5	p - q
aperture	very wide	wide	rather wide	rather narrow	narrow	very narrow
= fig.	1 a	2 a	3 a	5	-	4 a
post. outlet	0°	30°	60°	90°	120°	150°
= fig.	1 b	2 b	5 b	-	3 b	4 b

It seems useful to publish a complete list of the examined specimens (preserved in CS = coll. Schilder or BM = British Museum, Natural History) and good pictures published in various papers (marked with an asterisk *) so that students can plot other pairs of characters (or sums of characters) against each other if they think such an arrangement more apt to distinguish the species than the way I have published below. Each specimen is indicated first by a letter designating the species to which it seems to belong according to my investigations, viz.:

c = *carolinensis* *h* = *hughesi* *p* = *problematica*
t = *transitoria*

the letter is followed by a formula composed of figures which indicate the observed class in the five characters enumerated above: the first figure indicates the length, the second figure indicates the class of breadth, etc. (for each character the low figures indicate tendency toward *carolinensis*, high figures characterize *problematica*; x = class unknown).

Florida

St. Petersburg, Pinellas Cty.:
* Olsson & Harbison, 1953, pl. 27, fig. 2 (*problematica*): *p* 35455

Acline, Charlotte Cty., "Pliocene":
CS (don. Helen Tucker, 1933): *p* 44556, *p* 55646, *p* 36556, *p* 56646

Fort Denaud, Caloosahatchee River, Hendry Cty.
CS (leg. Donovan, 1943; don. Donovan, 1964): *p* 45655, *p* 34646, *p* 45456, *p* 35556

Fort Thompson, Caloosahatchee River, Hendry Cty.:
* Heilprin, 1887, pl. 4, fig. 12 (holotype of *problematica*): *p* 56556
* Du Bar, 1958, pl. 11, fig. 1 (*problematica*): *p* 36x56

Caloosahatchee River, Hendry and Glades Counties:
* Heilprin, 1887, pl. 16a, fig. 73 (*problematica*): *p* 35xx6
* Cossmann, 1903, pl. 7, figs. 3, 7 (*problematica*): *p* 45655
CS (from an old collection): *p* 45556
BM (No. 11809, from W. F. Webb, Albion, N. Y.): *p* 45556, *p* 45556, *p* 46456, *p* 56556, *p* 55656
BM (Nos. 4782 and 9523, no collector): *p* 45454, *p* 34455, *p* 46456

Harney Pond Canal, Glades Cty. (WNW of Lake Okeechobee):
* Olsson & Petit, 1964, pl. 83, fig. 4 (*problematica*, Caloosahatchee marl): *p* 65466
CS (leg. Raeihle, 1961; don. Old, 1963): *p* 35445, *p* 45455, *p* 44446
CS (leg. Emerson, 1960; don. Old, 1964): *p* 45445, *p* 45455, *p* 46556, *p* 46556

Clewiston, Hendry Cty. (SW of Lake Okeechobee):
CS (leg. Donovan, 1962; don. Donovan, 1964): *h* 21223, *t* 54345, *p* 46556
CS (leg. Donovan, 1963, don. Donovan, 1964): *h* 31123, *h* 33334, *t* 43444, *p* 35446, *p* 45556

Kissimee, Okeechobee Cty. (15 miles NNW of Lake Okeechobee):
CS (leg. Donovan, 1963; don. Summers, 1963): *h* 23232, *h* 22332, *h* 22223, *h* 32423, *h* 42423, *t* 46244, *t* 44454, *t* 43335, *t* 44445, *p* 33456, *p* 45456, *p* 35466
CS (leg. Donovan, 1963; don. Donovan, 1964): *h* 43323, *h* 53233, *t* 34554, *t* 55245, *t* 54355, *p* 35545, *p* 44455, *p* 44456, *p* 45456, *p* 46666

Brighton, Okeechobee Cty. (NW of Lake Okeechobee):
* Olsson & Petit, 1964, pl. 83, fig. 3 (holotype of *transitoria*, Pinecrest beds): *t* 64335
* Olsson & Petit, 1964, pl. 83, fig. 5 (holotype of *hughesi*, Pinecrest beds): *h* 51343

CS (leg. Donovan, 1962; don. Summers, 1963): *h* 33222 jun., *h* 33223, *h* 54233, *h* 31233, *h* 43333, *h* 52333, *h* 44314, *h* 53224, *h* 43424, *t* 43235 juv., *t* 33345, *p* 55456

CS (leg. Donovan, 1962; don. Donovan, 1964): *h* 32222, *h* 33123, *h* 64324, *t* 44354, *t* 62435

CS ("Brighton or Clewiston" don. Donovan, 1963): *h* 42334, *h* 23244, *t* 54335

Tarrytown, Indian Pierce Canal near Brighton, ibid.:

CS (leg. Donovan, 1963; don. Summers, 1963): *p* 54556

Tamiami Trail 42 miles W of Miami, Dade and Monroe Counties (13 miles E of Pinecrest):

*Mansfield, 1931, pl. 1, figs. 2, 7 (holotype of *floridana*): *f* 64221

*Mansfield, 1931, pl. 1, fig. 6 (paratype of *floridana*): *f* 52221

*Olsson & Petit, 1964, pl. 83, fig. 2 (*floridana*, Pinecrest): *f* 66321

Acline, Charlotte Cty. (see also above):

*Tucker & Wilson, 1932, pl 5, figs. 4, 5 (*floridana*): *f* 64211

Port Charlotte, Charlotte Cty.:

CS (don. DuBar, 1964: "Tamiami beds"): *f* 321.11, *f* 51221, *f* 43311, *f* 34411, *f* 45321, *f* 23112

North (and South) Carolina

Natural Well, Duplin Cty., North Carolina:

*Gardner, 1948, fig. 2 (*carolinensis*): *c* 44xx1

*Olsson & Petit, 1964, pl. 83, fig. 1 (*carolinensis*): *c* 63111

Duplin Cty., North Carolina:

*Conrad, 1841, pl. 2, fig. 6 (holotype of *carolinensis*): *c* 43211

BM (No. 7893): *c* 53112, *c* 54211

North Carolina:

*Emmons, 1858, fig. 131 (*carolinensis*): *c* 42111

*Cossmann, 1903, pl. 7, figs. 5, 9 (*carolinensis*): *c* 54111

Pee Dee, Horry District, South Carolina:

*Tuomey & Holmes, 1857, pl. 27, figs. 1, 2 (*carolinensis*): *c* 42311

Cape Fear River, North Carolina:

*Ingram, 1939, pl. 9, fig. 2 (holotype of *pilsbryi*): *c* 12211; ibid. p. 120 (paratype of *pilsbryi*): *c* 11xxx

There is a distinct correlation between the four last named characters, e. g. the classes of breadth and dentition, and the classes of aperture and posterior outlet:

dentition \ breadth	1	2	3	4	5	6
6	-	-	-	1	4	2
5	-	-	-	3	6	6
4	-	3	3	7	13	2
3	1	4	6	7	1	1
2	3	4	8	4	1	1
1	1	2	4	1	-	-

posterior outlet \ aperture	1	2	3	4	5	6
6	-	-	-	5	23	3
5	-	-	5	7	8	-
4	1	3	3	3	4	-
3	-	8	4	1	-	-
2	2	2	2	-	-	-
1	11	5	-	-	-	-

The length, however, varies rather independently from the other characters, e. g. from the posterior outlet:

posterior outlet \ length	1	2	3	4	5	6
6	-	-	8	16	7	1
5	-	-	5	9	4	2
4	-	1	2	8	1	1
3	-	2	5	3	4	-
2	-	2	2	-	1	-
1	1	1	2	6	4	4

Therefore we can add the figures indicating the breadth, dentition, aperture, and three times the figure indicating the posterior outlet, as it is evidently the most important character in the evolution of *Siphocypraea*; the length should be omitted altogether. If we plot these sums of characters against the various localities we obtain the following diagram:

	Sum	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
M	St. Petersburg																							1							
L	Acline																										1	1	2		
K	Fort Denaud																									1	2	1			
J	Fort Thompson																												1		
H	Caloosahatchee																				1		1			1		5	2		
G	Harney Pond										*hughesi*												2	2	1			1	2		
F	Clewiston							1	1							1		1			1					1		1	1		
E	Kissimmee								2	1		4							2	1	2	2	1	1	1	1	2	1			1
D	Brighton						1	1		2	1	2	2	2	2	2		1	2	3							2				
C	Tamiami			1		1			1										*transitoria*								*problematica*				
B	Acline, P. Char.	1	1		1	2	1	1			*floridana*																				
A	Carolina	1	2	3	1	1	*carolinensis*																								

▭ valid taxa (with names) ◯ holotypes

In this table the localities have been arranged according to the presumable geological age of the strata in which the fossil shells have been collected. According to OLSSON & PETIT (1964, p 514) the Upper Miocene Duplin age of Carolina (A) is contemporary with the Pinecrest beds of Florida; but from the successive development of characters in *Siphocypraea* I suspect that they are slightly older, even older than the Pinecrest beds from which *S. floridana* came (B, C). In the (possibly upper) Pinecrest beds around Lake Okeechobee (D - F) the two intermediates named by OLSSON & PETIT in 1964 occur in different percentages, but these localities also supply the true *S. problematica,* probably coming from the uppermost cowrie-bearing beds, the Pliocene Caloosahatchee marls. The absence of these intermediates in the remaining localities (G - L) may be accidental, as the Pinecrest beds also occur there underlying the Caloosahatchee marls from which the collected *S. problematica* undoubtedly came.

The taxonomy of the six taxa *pilsbryi, carolinensis, floridana, hughesi, transitoria* and *problematica* is difficult to be decided, as there is a continuous development of characters; these characters do not change equally as in every specimen some characters may be rather primitive, while other characters are more advanced, so that the sum of characters only indicates the place of the shell within the trend of evolution. In my opinion three species can be distinguished:

Siphocypraea HEILPRIN

(differs from the other Cypraeorbini with smooth fossula by the flat, slightly umbilicate spire)

(Akleistostoma) GARDNER

(posterior outlet vertical as in other Cypraeidae)

1. *S. (A.) carolinensis* (CONRAD) from late Miocene beds of Carolina with the local dwarf variety *pilsbryi* (INGRAM) and the often more callous geographical (and probably also stratigraphical) subspecies *floridana* (MANSFIELD) from the late Miocene Pinecrest beds of Florida.

(Siphocypraea) HEILPRIN

(posterior outlet dilated above to being recurved)

2. *S. (S.) hughesi* OLSSON & PETIT with its ecological (or also younger stratigraphical?) subspecies *transitoria* OLSSON & PETIT from Pinecrest beds of central Florida: *hughesi* approaches *floridana,* while *transitoria* gradually passes into *problematica.*
3. *S. (S.) problematica* (HEILPRIN) from the Pliocene Caloosahatchee marls of Florida with exaggerated characters of the posterior outlet which probably caused this extreme terminal offspring to become extinct since Pleistocene times.

The following key may be useful to identify the taxa of *Siphocypraea.*

1	Posterior outlet vertical, parallel-sided as in other cowries	2
-	Posterior outlet dilated or recurved in its upper part	4
2	Base flattened	3
-	Base mostly convex to swollen	***S. carolinensis floridana***
3	Shell less than 30 mm long	***S. carolinensis pilsbryi***
-	Shell more than 30 mm long	***S. carolinensis carolinensis***
4	Posterior outlet dilated above, but hardly recurved	*S. hughesi hughesi*
-	Posterior outlet distinctly recurved to the right	5
5	Posterior outlet rather recurved, aperture wide	*S. hughesi transitoria*
-	Posterior outlet extremely recurved, aperture narrow	*S. problematica*

Color. One *Siphocypraea carolinensis* (British Museum) seems to exhibit large brown blotches on the dorsum, while in *S. hughesi* and in *S. problematica* the dorsum is more finely punctate with fulvous; in *S. floridana, S. hughesi* and *S. problematica* several specimens show still the brown color of the teeth as it is in the recent *S. (Muracypraea) mus* (LINNAEUS).

SUMMARY

There is a gradual evolution of several morphological characters in the Neogene *Siphocypraea,* by the sum of which three species and two subspecies can be distinguished; the excessive development of the posterior outlet in the Pliocene *S. problematica* seems to have caused the extinction of this group of cowries.

In future collecting these fossils the exact position of each specimen within the stratigraphical beds should be indicated carefully so that the chronological development of characters could be shown more accurately than in this paper.

ACKNOWLEDGMENTS

I wish to express my sincere thanks to American scientists who donated many specimens of *Siphocypraea* so rarely represented in collections in Europe: especially to Mrs. J. W. Donovan who supported my studies by giving me many shells as well as maps of Florida, etc.; to Mr. J. R. Du Bar; W. E. Old, Jr.; R. Summers; Dr. A. A. Olsson; and Miss H. Tucker who sent me specimens, papers or information concerning the present study.

LITERATURE CITED

Conrad, Timothy Abbott

1841. Appendix to J. T. Hodge, Observations on the Tertiary of the southern Atlantic states. Silliman's Amer. Journ. Sci. 41: 346; plts.

Cossmann, Alexandre Édouard Maurice

1903. Essais de paléoconchyliologie comparée, vol. 5 (Paris)

Dall, William Healey

1890. Contributions to the Tertiary fauna of Florida. Trans. Wagner Free Inst. 3 (1)

Donovan, James W. & Virginia Donovan

1963. Letter. Seafari (a type-written periodical published by the Palm Beach County Shell Club), October 1963

Du Bar, Jules R.

1958. Stratigraphy and paleontology of the late Neogene strata of the Caloosahatchee River area of southern Florida. Florida Geol. Survey, Geol. Bull 40; 267 pp.; 12 plts.

Emmons, Ebenezer

1858. Mollusca, in: Report North Carolina Survey. Raleigh.

Gardner, Julia

1948. Mollusca from the Miocene and Pliocene of Virginia and North Carolina (II.) U. S. Dept. Inter., Geol. Survey, Prof. Paper 199B, p. 179

Heilprin, Angelo

1887. Explorations on the west coast of Florida and in the Okeechobee wilderness. Trans. Wagner Free Inst. 1: 1 to 134; 19 plts.

Ingram, William Marcus

1939. A new fossil cowry from North Carolina. The Nautilus 52 (4): 120 - 121; plt. 9, fig. 2

Mansfield, W. C.

1931. Some Tertiary mollusks from southern Florida. Proc. U. S. Nat. Mus. 79 (21): 12 pp.; 4 plts.

Olsson, Axel A. & Anne Harbison

1953. Pliocene mollusca of southern Florida. Acad. Nat. Sci. Phila. Monogr. 8: 1 - 457; plts.

Olsson, Axel A. & Richard E. Petit

1964. Some Neogene mollusca from Florida and the Carolinas. Bull. Amer. Pal. 47 (217): 505 - 574; plts. 77 - 83

Schilder, Franz Alfred

1926. Additions and corrections to Vredenburg's classification of the Cypraeidae. Rec. Geol. Surv. India 58 (4): 358 to 379

1932. Cypraeacea. In Fossilium Catalogus I: Animalia, part 55: 276 pp.

1941. Verwandtschaft und Verbreitung der Cypraeacea. Arch. Molluskenk. 73 (2 - 3): 57 - 120; 2 plts.

1958. Die Bezeichnung der Zahndichte der Cypraeacea. Arch. Molluskenk. 87 (1/3): 77 - 80

Tucker, Helen I. & Druid Wilson

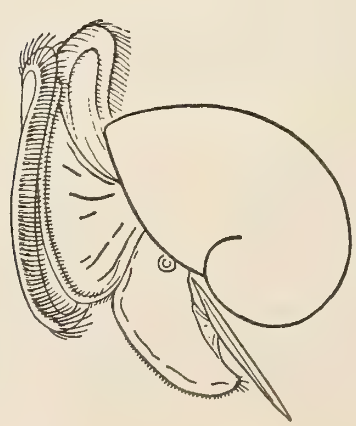
1932. Some new or otherwise interesting fossils from the Florida Tertiary. Bull. Amer. Pal. 18 (65)

Tuomey, M. & F. S. Holmes

1857. Pliocene fossils from South Carolina (Charleston)

Woodring, Wendell Phillips

1957. *Muracypraea*, a new subgenus of *Cypraea*. The Nautilus 70 (3): 88 - 89



New Terebrid Species from the Indo-Pacific Ocean and from the Gulf of Mexico,

with New Locality Records and Provisional Lists of Species Collected in Western Australia and at Sabah, Malaysia

(Mollusca: Gastropoda)

BY

R. D. BURCH

Post Office Box 461, Winton, California 95388

(Plate 31)

The continued interest in the collection and study of mollusca, coupled with improvements in equipment for dredging and diving, keeps adding to the known fauna of relatively well-explored waters and makes possible the compilation of check lists for less-known areas and the description of species heretofore not recorded in the literature.

Through the interest and generosity of a number of individuals and institutions new locality records or range extensions can be noted here, and provisional lists of terebrid species are possible for several areas for which there is little reference material available. The new locality records are noted here immediately following the description of the last new species described from the particular area. It is my intention to avoid, if possible, adding to the confusion of the taxonomic problems of this family; therefore, I have conservatively assigned all species to the broad generic groups of *Duplicaria, Hastula* and *Terebra,* with the use of such other supraspecific taxa as have been employed by previous authors. Since it has not been possible to make anatomical examinations necessary for an exact generic assignment of the various species, all such designations are made tentatively on the basis of shell characters alone.

In some areas such as Hawaii and Japan, from which new species or new locality records are noted, the collecting has been relatively intensive for many years and several lists of species have been compiled and published. All new records and range extensions noted here for such areas have been set down only after an examination of the literature.

Hastula (Hastula) tiedemani R. D. Burch, spec. nov.

(Plate 31, Figure 6)

Description: Shell very small, moderately subulate in shape, with flat-convex whorls; sculpture of straight, sharp, strong axial ribs extending from suture to suture on each whorl, fading at the periphery of the body whorl; interstitial spaces between the ribs smooth with no spiral sculpture; protoconch of three and one-half conical whorls, amber colored, darker on the anterior part. Shell color a shining white, with a faint light-brown wide band on the anterior portion of the whorls, extending around the base of the body whorl anterior to the periphery. Aperture narrow; columella straight, simple; siphonal canal a little reflected. Length 6.0 mm; width 1.5 mm.

Holotype: Museum of Comparative Zoology, Harvard University, No. 251237.

Type Locality: The holotype was collected at 50 foot depth with the use of diving equipment by Mr. Alan Tiedeman in Maalaea Bay, off Kihei, Maui, Hawaii, in January, 1964. Lat. 20° 46′ N; Long. 156° 30′ W.

Discussion: This minute species must be considered very rare since only a single specimen has been obtained during the extensive collecting in the Hawaiian Islands. This may be partially attributable to the very small size; it is the smallest species of *Hastula* known to me. The holotype is an adult specimen of six complete whorls in addition to the protoconch, and the body whorl exhibits the characteristics found in adult specimens of the genus. *Hastula tiedemani* resembles *H. albula* (Menke, 1843) (= *H. casta* (Hinds, 1844)), except that *H. albula*

is very much larger with wider and more obese whorls. *Hastula tiedemani* differs from *H. medipacifica* Pilsbry, 1921, which has also suture-to-suture axial ribs, in that the former is very much shorter, with a narrower apical angle and a different color arrangement. The sculptural variations of both *H. albula* and *H. medipacifica,* the two species which most closely resemble *H. tiedemani,* are in all instances much larger and wider, with a greater apical angle, and the width of the aperture proportionately greater.

An effort has been made to secure additional specimens; however, the rarity and small size of this species have combined to prevent the collection of any other specimens. These factors have determined that this species be described from the unique specimen designated as the holotype.

This species is named in honor of Mr. Alan Tiedeman for his numerous additions to the knowledge of the terebrid species indigenous to Hawaii.

Hastula (Hastula) maryleeae R. D. Burch, spec. nov.

(Plate 31, Figure 4)

Description: Shell small, moderately subulate, with flat-concave whorls; color dark brown, with an obscure white band at the periphery of the body whorl; sculpture of low, thin axial ribs on the posterior one-third of each whorl; anterior portion unsculptured; body whorl with a series of low, thin, weak semi-nodules at the periphery, not connecting with the crenules on the posterior portion and not extending to the base of the shell; protoconch of two glassy whorls; aperture effuse and moderately laminated on the columellar wall; columella short, straight, with a single strong plication. Length 23.7 mm; width 5.0 mm.
Holotype: Museum of Comparative Zoology, Harvard University No. 251235
Type Locality: The holotype and 20 paratypes were collected in sand at low tide on March 16, 1961, by Mrs. Mary Lee Burch at Surfside Beach, Freeport, Texas. Lat. 28° 57′ N; Long. 95° 38′ W.
Paratypes: Since this species has been taken in numbers by several collectors, paratypes are being deposited in a number of major institutions. Additional paratypes will remain in the collections cited in Table 1.
Discussion: This small species is regarded as uncommon along the Texas coast in a area bounded by Freeport, Texas, on the east and by Padre Island on the west. It is rather variable in both sculpture and color, with about 40% of specimens examined having the peripheral crenules on the body whorl entirely obsolete and replaced with a continuous swelling that forms a wide convex belt. The peripheral crenules or swellings on the body whorl, together with the crenules of the subsutural band, combine to give the outline of the whorls a concave appearance. As with many other species of the genus *Hastula,* this species often produces colorless or albino varieties; hypotype (21) is a solid opaque white. Other color variations between the dark brown of the holotype and the pure white of hypotype (21) most often show a light area immediately anterior to the suture, followed by a dark gray or purplish color which extends to the periphery of the body whorl where it is interrupted by a band of white before continuing to the base of the whorl. *Hastula maryleeae* differs from *H. hastata* (Gmelin, 1791) in that the former is more slender in form and does not have the continuous suture-to-suture axial ribs of the latter. It also differs from *H. cinerea* (Born, 1780) and *H. salleana* (Deshayes, 1859) in that it possesses a row of small crenules, occasionally coalesced into a broad belt at the periphery of the body whorl.

This species is named in honor of Mrs. Mary Lee Burch for her understanding and assistance during the sometimes tedious days of this study and for having collected the first specimens which brought this species to my attention.

Hastula (Hastula) maryleeae

Table 1

Specimen	Collection	Locality	Collector
Holotype	M. C. Z. No. 251235	Surfside Beach, Freeport, Texas	M. L. Burch
Paratypes 1, 2	M. C. Z. No. 251236	Surfside Beach, Freeport, Texas	M. L. Burch
Paratype 3	Natal Mus., South Africa No. 1067	Surfside Beach, Freeport, Texas	M. L. Burch
Paratypes 4, 5	Tiedeman Coll.	Surfside Beach, Freeport, Texas	M. L. Burch
Paratypes 6, 7	Campbell Coll.	Surfside Beach, Freeport, Texas	M. L. Burch
Paratypes 8 - 20	R. D. Burch Coll. No. 023	Surfside Beach, Freeport, Texas	M. L. Burch
Hypotype (21)	R. D. Burch Coll. No. 466	"Padre Island," Texas	C. Ivey
Hypotypes (22 - 26)	Webb Coll.	"Mustang Island," Texas	K. Webb

Hastula (Punctoterebra) betsyae R. D. Burch, spec. nov.

(Plate 31, Figure 2)

Description: Shell small and moderately subulate, with flat-convex whorls, sculptured with low, slightly bent, angular ribs which are contiguous with the sutures on the early whorls and fading at the periphery of the body whorl; interstices between each axial rib contain a single depressed punctation at about one-third the whorl's width from the posterior suture; punctations not connected across the ribs forming an interrupted line of spiral sculpture; color pattern a series of irregular axial brown lines or flammules which occasionally coalesce to form interrupted spiral bands of color on the basically white shell; protoconch with three conical, glassy whorls; aperture oblong-ovate; columella straight and slightly angled; siphonal canal recurved. Length 34.0 mm; width 7.0 mm.
Holotype: Museum of Comparative Zoology, Harvard University No. 251238
Type Locality: The holotype and 47 paratypes were collected in sand at 20 feet with the use of diving equipment by Mr. Alan Tiedeman off Honokohau, Maui, Hawaii, in December, 1963. Lat. 21° 04′ N; Long. 156° 38′ W.
Paratypes: This relatively common species, which appears to be endemic to the Hawaiian Islands, has been taken in large numbers by several collectors. Paratypes are deposited in a number of major institutions. Additional paratypes will remain in the collections cited in Table 2.
Discussion: *Hastula betsyae* resembles *H. penicillata* (Hinds, 1844), except that a single punctation is present in each interstice of the former, while this interstitial space is not punctate in the latter. An examination of numerous specimens of *H. penicillata* from various localities in the Pacific and Indian oceans, together with a scrutiny of the various check lists and the literature published to date, has failed to disclose a single specimen of *H. penicillata* with an indication of the punctate sculpture displayed uniformly by each of over 400 examples of *H. betsyae* collected at Hawaiian localities, all of which have been examined under magnification. Except for various arrangements of the color pattern, *H. penicillata* is remarkably consistent in sculpture throughout its entire range eastward in the Pacific ocean to Easter Island; however, it appears that the species does not occur in the Hawaiian Islands. *Hastula betsyae* is the species referred to as *H. penicillata* (Hinds) by Tinker, 1958 (p. 198) and Weaver, 1960 (vol. 1, no. 5, bottom row).

This species is named in honor of Miss Betsy Clarke Harrison for having collected the specimens which first brought the species to my attention.

In addition to the new species *Hastula tiedemani* and *H. betsyae* described above from the recent collecting in the Hawaiian Islands, a number of additions to the published records of the fauna can now be noted. Through the efforts and interest of Mrs. Elizabeth Harrison, Mr. C. S. Weaver and Mr. Alan Tiedeman, the following should be included among the terebrids of Hawaii as listed by Pilsbry (1921), Mant (1923), Tinker (1952, 1958), Weaver (1960 - 1961), and various issues of The Hawaiian Shell News.

Hastula (Punctoterebra) anomala **(Gray, 1834);**
Proc. Zool. Soc. London, p. 62; Fig.: Hinds in Sowerby, Thes. Conch., *Terebra,* 1844, pl. 44, fig. 97. This species superficially resembles *H. inconstans* (Hinds, 1844). It may be distinguished by a single row of punc-

Table 2

Hastula (Punctoterebra) betsyae

Specimen	Collection	Locality	Collector
Holotype	M. C. Z. No. 251238	Honokohau, Maui, Hawaii	A. Tiedeman
Paratypes 1, 2	M. C. Z. No. 251239	Honokohau, Maui, Hawaii	A. Tiedeman
Paratypes 3 - 7	San Diego Mus. Nat. Hist. No. 48930	Honokohau, Maui, Hawaii	A. Tiedeman
Paratypes 8 - 10	Natal Mus., South Africa No. 1068	Honokohau, Maui, Hawaii	A. Tiedeman
Paratypes 11 - 14	Tiedeman Coll.	Honokohau, Maui, Hawaii	A. Tiedeman
Paratypes 15 - 18	Campbell Coll.	Honokohau, Maui, Hawaii	A. Tiedeman
Paratypes 19 - 22	Weaver Coll.	Honokohau, Maui, Hawaii	A. Tiedeman
Paratypes 23 - 26	Harrison Coll.	Honokohau, Maui, Hawaii	A. Tiedeman
Paratypes 27 - 47	R. D. Burch Coll. No. 172	Honokohau, Maui, Hawaii	A. Tiedeman
Hypotypes (48 - 52)	R. D. Burch Coll. No. 353	Haleiwa Bay, Oahu, Hawaii	B. Harrison
Hypotypes (53 - 56)	R. D. Burch Coll. No. 532	Waianae Bay, Oahu, Hawaii	C. Weaver

tations that occasionally coalesce to form a thin shallow subsutural groove. Collected at 20 feet off MacGregor's Landing, Maui, by Alan Tiedeman, Jan., 1964, and littorally at Nanakuli, Oahu, by Mrs. Jean Bromley in 1959. R. D. Burch Coll. Nos. 621, 622.

Terebra (Dimidacus) amanda Hinds, 1844;
Proc. Zool. Soc. for 1843, p. 154; Fig.: Hinds in Sowerby; Thes. Conch., 1844, *Terebra,* pl. 45, fig. 100. Collected at 35 feet in Pokai Bay, Oahu, by Mrs. Elizabeth Harrison on June 22, 1962, and at 80 feet, under sand in Waianae Bay, Oahu, by C. S. Weaver on August 29, 1963. R. D. Burch Coll. Nos. 405, 533.

Terebra (Strioterebrum) cancellata Quoy & Gaimard, 1832; Voy. Astrol., Moll., vol. 2, p. 471, plt. 36, figs. 27, 28 (*non* Röding, 1798, = *T. anilis* Röding, 1798); *non* Gray, 1834, = *T. undatella* Deshayes, 1859; *non* Cossmann, 1900, = *T. intermedia* Vredenburg, 1921). Two specimens collected under four inches of sand by C. S. Weaver at Nawiliwili, Kauai, in April, 1956. C. N. Cate Coll. No. 052.

Terebra (Decorihastula) marmorata Deshayes, 1859;
Proc. Zool. Soc. London, p. 279, no. 21; Fig.: Reeve, Conch. Icon., 1860, *Terebra,* plt. 19, figs. 91 a, b. Specimens collected at 30 feet, in sand, off the Bureau of Standards Timing Station, Kihei Lagoon, Maui, by Mr. Joe Kern during 1964. Excellent specimens are in the Kern Coll. and Tiedeman Coll.; R. D. Burch Coll. No. 661.

Terebra (Decorihastula) nebulosa Sowerby, 1825;
Tank. Cat. App., p. 25 (*non* Kiener, 1838, = *T. candida* (Born, 1780); *non* Lorois, 1858, = *T. guttata* (Röding, 1798)). Collected at 35 feet in Pokai Bay, Oahu, by Mrs. Elizabeth Harrison on June 22, 1962. R. D. Burch Coll. No. 406.

Terebra (Perirhoe) tricolor Sowerby, 1825;
Tank. Cat. App., p. 24. Two specimens collected at 30 feet off MacGregor's Landing, Maui, by Alan Tiedeman during August, 1964. Tiedeman Coll. No. 1386.

Hastula (Punctoterebra) cernohorskyi **R. D. Burch, spec. nov.**

(Plate 31, Figure 3)

Description: Shell of medium size, moderately subulate in form; color light brown or light olive-green throughout; a lighter shade immediately anterior to the sutures, and a darker band below the periphery of the body whorl extends to the siphonal canal with little contrast; early sculpture of low, rounded, close-set axial ribs contiguous with the sutures; ribs becoming shorter in succeeding whorls until they extend only over the posterior one-fourth of the whorl. At the sixth whorl, the axial ribs extend over the posterior one-half of the whorl and are microscopically punctate in the rib interstices. The single interstitial punctation, located on the posterior one-fourth of the whorl, intersects the edges of the ribs and forms an obsolete, narrow, shallow subsutural groove which continues to the aperture. Whorls flat-convex; aperture oblong-ovate and slightly effuse at the base; columella short, slightly angled and moderately twisted, with two plications; columellar wall lightly laminated; siphonal canal moderately recurved. Length 54.0 mm; width 7.0 millimeters.

Holotype: Museum of Comparative Zoology, Harvard University No. 251245

Type Locality: The holotype and 7 paratypes, all dead specimens devoid of animal, were collected littorally or by dredging over a sand bottom in shallow water off Natadola, Fiji Islands, by Mr. W. O. Cernohorsky during 1961 and 1962 and by Mr. A. Morse in 1959. Lat. 18° 06′ 40″S; Long. 177° 19′ 30″E.

Paratypes will remain in the collections cited in Table 3.

Discussion: *Hastula cernohorskyi* has no closely-resembling species with which it might be confused, although some superficial similarity exists in *H. anomala* (Gray, 1834). With *H. cernohorskyi,* the crenules anterior to the suture are smaller, more rounded and close-set than in *H.*

Table 3

Hastula (Punctoterebra) cernohorskyi

Specimen	Collection	Locality	Collector
Holotype	M. C. Z. No. 251245	Natadola, Fiji Islands	W. Cernohorsky
Paratypes 1 - 5	Cernohorsky Coll.	Natadola, Fiji Islands	A. Morse
Paratype 6	Jennings Coll.	Natadola, Fiji Islands	A. Morse
Paratype 7	R. D. Burch Coll. No. 633	Natadola, Fiji Islands	A. Morse
Hypotype 1	Currin Coll.	Unknown, "bought from fisherman in Philippines"	
Hypotype 2	Miller Coll.	Leleuvia Island, Fiji Islands	cited from observation of W. Cernohorsky

anomala and extend only about one-fourth the distance across the whorl, while in *H. anomala* they extend to and beyond the periphery of the body whorl. The aperture of *H. cernohorskyi* is less effuse than that of *H. anomala*, and the columellar wall has less laminations. The distinctive uniform color of *H. cernohorskyi* will distinguish it from *H. anomala* and *H. lauta* (Pease, 1869), as will the greater apical angle and much larger size.

Hastula cernohorskyi is considered by the author to be endemic to the southern Fiji Islands and presently very rare. It is probably the second-largest species of the genus, only *H. caerulescens* (Lamarck, 1822) exceeding it in size.

This species is named in honor of Mr. Walter Oliver Cernohorsky in recognition of his considerable contributions to the literature of the molluscan fauna of the Fiji Islands and for having collected the specimens which first brought the species to my attention.

Duplicaria (Duplicaria) crakei R. D. Burch, spec. nov.

(Plate 31, Figure 1)

Description: Shell small, moderately subulate, with flat-convex whorls; color pale yellow, occasionally suffused or blotched with brown anterior to the subsutural groove and extending just below the periphery of the body whorl, followed by a wide blue-purple band anterior to the periphery covering the base of the shell; bottom of the subsutural groove colored same as base of shell with the color extending on to and occasionally suffusing the entire subsutural band; sculpture of straight, regularly-spaced, angular axial ribs, contiguous with the sutures and extending to the base of the body whorl. A deep spiral subsutural groove divides the whorls about one-third of their width from the posterior suture, setting off a subsutural band of axially-lengthened straight crenules which are continuations of the ribs anterior to them. No other spiral sculpture than that formed by the subsutural groove. Protoconch paucispiral, of two and one-half conical, amber-colored whorls which are a darker shade on the posterior half of each whorl; columella very twisted, of same color as base of shell, with a single strong plication that is yellow or white; siphonal canal very recurved. Length 23.0 mm; width 5.5 mm.

Holotype: Museum of Comparative Zoology, Harvard University No. 251241

Type Locality: The holotype and 97 paratypes were collected in fine sand at low tide on Cable Beach, Broome, Western Australia, during August of 1962, by Mr. Ted Crake. Lat. 18° 00′ S.; Long. 122° 15′ E.

Paratypes: The collection of sufficient paratypes has allowed for deposit in a number of private and major public collections. Numbered paratypes will be retained in the collections cited in Table 4.

Discussion: The distinctive colors and their arrangement, together with the polished shining surface, combine to make *Duplicaria crakei* one of the most beautiful of the terebrid species. There are infrequent color variations in which the blue-purple color of the predominant form is replaced by various shades of brown, and in these a wide pale-brown color band, occasionally broken into blotches or spots, occupies the area immediately anterior to the subsutural groove and displaces about one-half of the yellow color of the predominant form. *Duplicaria crakei* is sculpturally similar to several other species but may be readily distinguished from them. It differs from *D. duplicata* (Linnaeus, 1758) in that its crenules of the subsutural band are axially straight and sharp, while in *D.*

Table 4

Duplicaria (Duplicaria) crakei

Specimen	Collection	Locality	Collector
Holotype	M. C. Z. No. 251241	Broome, West Australia	T. Crake
Paratypes 1 - 5	M. C. Z. No. 251242	Broome, West Australia	T. Crake
Paratypes 6 - 8	San Diego Mus. Nat. Hist. No. 48935	Broome, West Australia	T. Crake
Paratypes 9, 10	Natal Mus., South Africa No. 1069	Broome, West Australia	T. Crake
Paratypes 11 - 13	Campbell Coll.	Broome, West Australia	T. Crake
Paratypes 14, 15	Tiedeman Coll.	Broome, West Australia	T. Crake
Paratypes 16 - 97	R. D. Burch Coll. No. 336 No. 337	Broome, West Australia	T. Crake

duplicata they are slanted or curved and have a flattened or rounded appearance. It differs from *D. addita* (Deshayes, 1859) in that it has a deeper, wider subsutural groove setting off a less-rounded, less-turreted subsutural band, and a smaller apical angle. The sculptural differences are more apparent from *D. fictilis* (Hinds, 1844), *D. bicolor* (Angas, 1867), and *D. fuscobasis* (E. A. Smith, 1877) in that *D. crakei* has a wide, flat subsutural band set off by the sharp, deeply-cut subsutural groove rather than the narrow, rounded subsutural band and shallow impressed subsutural groove of those species. Both *D. macandrewi* (E. A. Smith, 1877) and *D. padangensis* (Thiele, 1925) have distinct microscopic interstitial spiral striations, while the interstices between the axial ribs of *D. crakei* are smooth and polished.

This species is named to honor Mr. Ted Crake for having collected the shells from which the species is described and for his generous assistance in providing specimens and information relative to the terebrid fauna of the area.

The collecting for terebrid species in Western Australia has been limited to small areas, and the fauna of much of the lengthy coastline remains relatively unknown. No check lists appear to have been published for the general area, although a few limited listings have been made from certain areas along the coast. Through the generous assistance of Mr. Anthony Kalnins of Riverton, Mrs. M. Seymour of Port Hedland and Mr. Ted Crake of Broome, the following species can be recorded here from Western Australia localities:

Genus *Hastula*

H. (Hastula) diversa (E. A. Smith, 1901); Journ. Conch. vol. 10, p. 115, plt. 1, fig. 6
Littoral, 200 miles south of Broome; R. D. Burch Coll. No. 340.

H. (Hastula) dispar (Deshayes, 1859); Proc. Zool. Soc. London, p. 284; fig.: Reeve, Conch. Icon., *Terebra*, plt. 25, fig. 137.
In fine sand at low tide, Broome. R. D. Burch Coll. No. 317.

H (Punctoterebra) lauta (Pease, 1869); Amer. Journ. Conch., vol. 5, p. 66; fig.: Weaver, Hawaiian Marine Mollusks, 1960, vol. 1, no. 8.
Littoral, Broome; R. D. Burch Coll. No. 534.

H. (Punctoterebra) nitida (Hinds, 1844); Proc. Zool. Soc. London for 1843, p. 152; fig.: Hinds in Sowerby, Thes. Conch., *Terebra*, 1844, plt. 45, fig. 103.
In sand at low tide. Port Hedland; R. D. Burch Coll. No. 462.

H. (Punctoterebra) plumbea (Quoy & Gaimard, 1832); Voy. Astrol., Moll., p. 470, plt. 36, figs. 29,30.
Littoral; Murumba, King Sound; R. D. Burch Coll. No. 376.

H. (Hastula) rufopunctata (E. A. Smith, 1877); Ann. Mag. Nat. Hist., p. 229. No figure seems to have been published for this species until now. - In sand at low tide, Broome; R. D. Burch Coll. No. 314; Port Hedland; R. D. Burch Coll. No. 628.

Genus *Duplicaria*

D. (Duplicaria) addita (Deshayes, 1859); Proc. Zool. Soc. London, p. 293; fig.: Reeve, Conch. Icon., 1860, *Terebra*, plt. 19, fig. 94. - Broome; R. D. Burch Coll. No. 338; and Port Hedland, R. D. Burch Coll. No. 476.

D. (Duplicaria) australis (E. A. Smith, 1873); Ann. Mag. Nat. Hist., p. 264; fig.: Hedley, Proc. Linn. Soc. New So. Wales, 1908, vol. 38, prt. 3, plt. 7, fig. 2.
King Sound, R. D. Burch Coll. No. 375; Broome. R. D. Burch Coll. No. 150; Port Hedland, R. D. Burch Coll. No. 464; and Cape Leveque, R. D. Burch Coll. No. 065.

D. (Duplicaria) duplicata (Linnaeus, 1758); Syst. Nat., Ed. 10, p. 742, no. 419; fig.: Gaultieri, Test., plt. 57, fig. N.
This species has been given a number of names which are primarily based on the many color variations and patterns, all of which are to be found among specimens collected in Western Australia. After longitudinally sectioning shells of various color and sculptural forms obtained from many areas, including eastern Africa and the Red Sea, I am unable to follow the arrangement for this species erected by Bartsch, in which the dark brown color form is given a new name, *Terebra duplicatoides*, and a new subgenus, *Myurellisca*, erected for it. (see Bartsch, Paul, 1923 - Nautilus 37 (2): 63 - 64).
Broome, R. D. Burch Coll. No. 111; Port Hedland, R. D. Burch Coll. No. 463; and Albany, King George Sound, R. D. Burch Coll. No. 081.

D. (Duplicaria) evoluta (Deshayes, 1859); Proc. Zool. Soc. London, p. 292; fig.: Reeve, Conch. Icon., 1860, *Terebra*, plt. 13, fig. 55 (*non* Hirase, 1917, plt. 2, fig. 11 and plt. 4, figs. 42 - 44; *non* Kira, 1959, plt. 70, fig. 17).
This species is often found in the same localities as *D. australis* and is occasionally intermingled with it in the same population. There is some question as to the relationship between these two species, since in some instances both forms have been collected together in a single track. For purposes of separating these closely related species it may be noted that *D. evoluta* has a base color of dark gray, brown or black, with a narrow white band anterior to the periphery of the body whorl. In *D. australis* the basic color is solid white or light orange. The bottom of the subsutural groove of *D. evoluta* is finely punctate when examined under magnification, while in *D. australis* it is smooth.

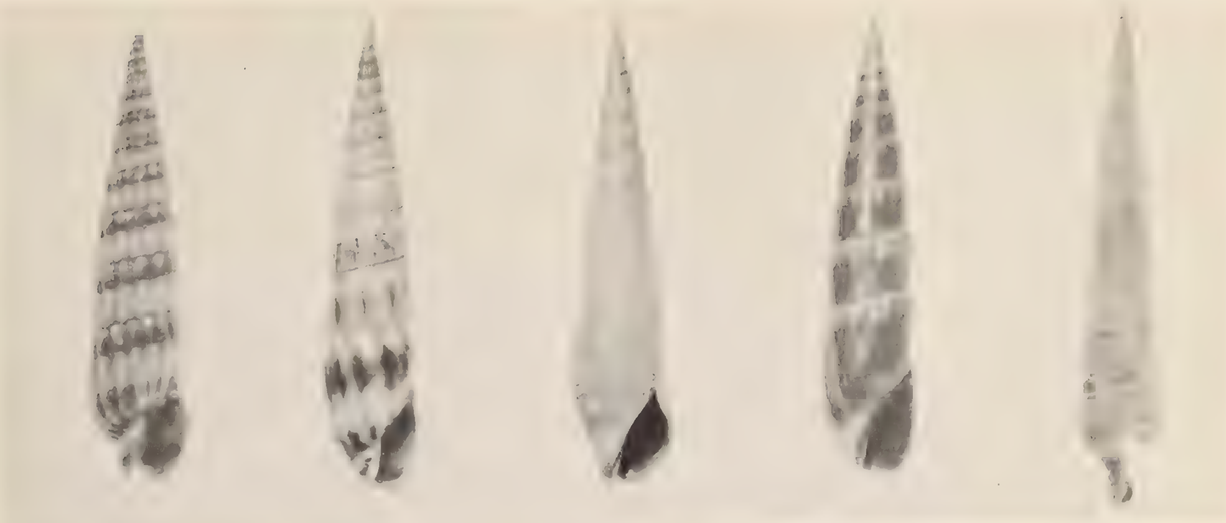


Figure 1 Figure 2 Figure 3 Figure 4 Figure 5

Figure 6 Figure 7 Figure 8 Figure 9 Figure 10

All figures are of the holotypes of the species described as new in this paper.

Figure 1: *Duplicaria crakei*; MCZ No. 251241 (x $2\frac{1}{2}$)
Figure 2: *Hastula betsyae*; MCZ No. 251238 (x 2)
Figure 3: *Hastula cernohorskyi*; MCZ No. 251245 (x 1)
Figure 4: *Hastula maryleeae*; MCZ No. 251235 (x $2\frac{1}{2}$)
Figure 5: *Terebra campbelli*; MCZ No. 251244 (x $2\frac{1}{2}$)
Figure 6: *Hastula tiedemani*; MCZ No. 251237 (x $9\frac{1}{2}$)
Figure 7: *Terebra montgomeryi*; MCZ No. 251240 (x $1\frac{1}{4}$)
Figure 8: *Terebra kilburni*; MCZ No. 251247 (x 2)
Figure 9: *Terebra jenningsi*; MCZ No. 251248 (x $1\frac{1}{4}$)
Figure 10: *Duplicaria teramachii*; MCZ No. 251243 (x 2)

G. BRUCE CAMPBELL *photo.*

Broome, R. D. Burch Coll. No. 465; a melanistic color form also occurs here infrequently, R. D. Burch Coll. No. 367.

D. (Pervicacia) ustulata (DESHAYES, 1857); Journ. Conchyl., p. 97, plt. 3, fig. 12.
Albany, King George Sound; R. D. Burch Coll. No. 618.

Genus *Terebra*

T. (Decorihastula) amoena DESHAYES, 1859; Proc. Zool. Soc. London, p. 297; fig.: REEVE, Conch. Icon., 1860, *Terebra*, plt. 18, fig. 80.
Port Hedland, R. D. Burch Coll. No. 460.

T. (Decorihastula) picta HINDS, 1844; Proc. Zool. Soc. London for 1843, p. 156; fig.: HINDS in SOWERBY, Thes. Conch., 1844, *Terebra*, plt. 45, fig. 105.
The specimens from Western Australia exhibit considerable variation in color, with the large majority being melanistic. Specimens collected at Murumba, King Sound, are of the color and color pattern of HINDS' description, while those collected from more southern localities are about 95% of the melanistic color variety. King Sound, R. D. Burch Coll. No. 377; Broome, R. D. Burch Coll. No. 339; and Port Hedland, R. D. Burch Coll. No. 477.

T. (Clathroterebra) violascens HINDS, 1844; Proc. Zool. Soc. London for 1843, p. 154; fig.: HINDS in SOWERBY, Thes. Conch., 1844, *Terebra*, plt. 45, fig. 98.
Broome, R. D. Burch Coll. No. 536.

The terebrid fauna of Australia, particularly that of the area included above, seems to be unique in the high proportion of species of the genera *Duplicaria* and *Hastula* to those of the genus *Terebra*.

Duplicaria (Duplicaria) teramachii R. D. BURCH, spec. nov.

(Plate 31, Figure 10)

Description: Shell of medium size with tight-wound, flat-convex whorls; basic color ivory-white, overlaid anterior to the subsutural groove with a broad, interrupted band of reddish-brown which, on the body whorl, extends to the base of the shell; body whorl anterior to the periphery encircled by a faint, narrow band of color, same as basic shell coloration; sculpture of thin, narrow, close-set, straight axial ribs contiguous with the sutures and extending weakly to the base. A narrow subsutural groove, more deeply impressed in the interstices, cuts the ribs about one-fourth the whorl width from the posterior suture, forming a subsutural band of crenules which are extensions of the axial ribs anterior to the groove; columella straight, with a single strong plication; columellar wall strongly laminated; aperture long and narrow. Length 37.0 mm; width 5.5 mm.

Holotype: Museum of Comparative Zoology, Harvard University No. 251243

Type Locality: The holotype was dredged at 70 fathoms off Tosa, in Tosa Bay, Japan, in 1962. Lat. 33° 25′ N; Long. 133° 32′ E.

Discussion: There are no species which closely resemble *Duplicaria teramachii* in form and sculpture although several species of the genus have a similar color or color pattern. The subsutural groove of *D. teramachii* is narrow, relatively shallow and more deeply cut at its juncture with the rib interstices; while in *D. duplicata* (LINNAEUS, 1758), *D. dussumieri* (KIENER, 1839), *D. evoluta* (DESHAYES, 1859) and *D. spectabilis* (HINDS, 1844) the groove is broad and much more deeply cut; a very broad impressed groove such as that displayed by *D. kirai* OYAMA, 1962, *D. latisulcata* (YOKOYAMA, 1922) and *D. recticostata* (YOKOYAMA, 1920) is even farther removed from that of *D. teramachii*. The subsutural groove of *D. albozonata* (E. A. SMITH, 1875) does not have the deep interstitial cut observed in *D. teramachii* and the subsutural band of that species is composed of slanted, wave-like crenules; with the columellar wall not laminated, a more obese form and different color pattern also distinguishing it from *D. teramachii*. The apical angle of *D. teramachii* is also narower than that of each of the above species. The color and color pattern of *D. tiurensis* (SCHEPMAN, 1913) are similar, but the more widely spaced axial ribs not extending beyond the periphery of the body whorl and the not-laminated columellar wall distinguish it from *D. teramachii*.

The evident rarity of *Duplicaria teramachii* and the depth from which it was trawled in Tosa Bay indicate that the species may justifiably be described from the unique specimen.

This species is named in honor of Mr. Akibumi Teramachi for his considerable contributions to the knowledge of the molluscan fauna of Japan and for having obtained the specimen from which the species is described.

Terebra (Strioterebrum) campbelli R. D. BURCH, spec. nov.

(Plate 31, Figure 5)

Description: Shell of medium size, very slender, with flat-convex whorls; basic color yellowish-white, with moderately-sized square or rectangular blotches of brown on the subsutural band occasionally extending onto the whorl anterior to the subsutural groove and a narrow, obscure white band at the periphery of the body whorl; sculpture of low, curved, rounded axial ribs; interstices of juvenile and sub-adult whorls bisected by numerous microscopic impressed striae; striations join across ribs of adult whorls to form about seven narrow, impressed spiral grooves;

axial ribs obsolete anterior to the periphery of the body whorl; a well-defined subsutural groove cuts the axial ribs about one-fourth the whorl's width from the posterior suture, creating a flat or slightly rounded subsutural band composed of straight or dextrally-slanted crenules which are occasionally microscopically striated in the interstices; whorls tightly wound, so that the subsutural band is even with, or slightly below, the sides of the adjacent whorl peripheries; columella straight, with no plications; columellar wall not laminated; siphonal canal moderately recurved. Length 25.5 mm; width 4.5 mm.

Holotype: Museum of Comparative Zoology, Harvard University No. 251244

Type Locality: The holotype and one paratype (R. D. Burch Coll. No. 510; length 30.7 mm, width 5.0 mm) were dredged in 70 fathoms off Tosa, Japan, in Tosa Bay. during 1963. *ex* A. Teramachi Coll. Lat. 33° 25′ N; Long. 133° 32′ E.

Discussion: *Terebra campbelli* resembles *T. picta* HINDS, 1844, except that in the latter the subsutural band is raised, giving the shell a turreted appearance, and the columella is slightly twisted, with a single moderately strong plication, while the subsutural band is level or slightly depressed in *T. campbelli,* with the columella straight and not plicated. The interstitial striations between the axial ribs of *T. campbelli* are much finer and more numerous while crossing the ribs of adult whorls, but this interstitial striation does not coalesce in *T. picta.* Other species which superficially resemble *T. campbelli* are *T. columellaris* HINDS, 1844, *T. amoena* DESHAYES, 1859, *T. gotoensis* E. A. SMITH, 1879, *T. pertusa* (BORN, 1780), *T. marmorata* DESHAYES, 1859, and *T. andamanica* MELVILL & SYKES, 1899, but all of these have a greater apical angle and a punctate interstitial striation that does not cut across the ribs as in *T. campbelli.*

This species is named in honor of G. Bruce Campbell in recognition of his generous assistance and for his contributions to the literature on the terebrid fauna of the western Americas.

In addition to the above new species, *Duplicaria teramachii* and *Terebra campbelli,* the efforts of Mr. Akibumi Teramachi have made possible the addition of the following terebrids to the lists of Japanese species compiled by HIRASE, 1917, KURODA & HABE, 1952, and OYAMA, 1961.

Terebra (Noditerebra) constricta THIELE, 1925: Deutsche Tiefsee Exped., Gastr., prt. 2, p. 347, plt. 30, fig. 5. [This specific name may be a homonym; see: HINDS, 1844; Proc. Zool. Soc. London for 1843, p.166, no. 116.] Dredged at 50 fathoms off Tosa, in Tosa Bay, Japan; *ex* A. Teramachi Coll. R. D. Burch Coll. No. 647.

Terebra (Noditerebra) pectinata (VREDENBURG, 1921); Rec. Geol. Surv. India, p. 355, plt. 10, fig. 20.
The present specimens are subfossil, with the protoconch and early whorls missing, and a heavy black deposit on the shells. The basic color appears to be solid orange, with perhaps a white peripheral band on the body whorl. - Dredged in 50 fathoms in Tosa Bay, Japan; 1962. *ex* A. Teramachi Coll. R. D. Burch Coll. No. 507.

Terebra (Triplostephanus) jenningsi R. D. BURCH, spec. nov.

(Plate 31, Figure 9)

Description: Shell of medium size, very slender and elongated, with flat-concave whorls; basic color a bright orange throughout, with a white band encircling the whorls anterior to the sutures and including both of the two crenate subsutural bands; protoconch of two and one-half opaque white dome-like whorls; following three whorls of the teleoconch have two rows of microscopic crenules anterior to the posterior suture and one row of similarly small beads at the anterior suture, with the intervening peripheral section of the whorl being flat-concave; succeeding whorls moderately concave between the crenules for about 22 turns, becoming more flat or flat-convex on later whorls. The double row of crenules, the posterior row being larger, becomes progressively obsolete until it has the appearance of a slightly raised broad belt, which is obsoletely nodular and broken only by the wrinkled axial growth lines. Anterior row of small, less well defined beads continues strongly throughout and around the periphery of the body whorl; at about the fourteenth whorl, the concave peripheral area of the whorls becomes spirally sculptured with four or five shallow, narrow impressed grooves, which are occasionally finely-punctate within, and with curved, arcuate axial growth lines; aperture ovate and flaring, constricted at the base; columella twisted, with the siphonal canal sharply recurved. Length 76.2 mm (with about 3.0 mm broken from apex); width 8.5 mm.

Holotype: Museum of Comparative Zoology, Harvard University No. 251248

Description of animal: I am indebted to Mr. W. O. Cernohorsky for his observations which make possible this description of the animal of *Terebra jenningsi.*

Siphon simple, of a pale yellow color which becomes bright yellow towards the extremity; eye-stalks short and pointed, cream-white with the black eyes situated slightly back from the tips; sole and dorsum of foot cream-white; foot truncated anteriorly and pointedly-rounded posteri-

orly; operculum narrow-elongate, translucent orange-yellow in color.

Type Locality: The holotype was dredged in three to four fathoms on clean sand substrate at the inner edge of the main barrier reef, one mile to the northwest of Namotu Island, Fiji Islands, by Mr. A. Jennings. Lat. 17° 50′ S; Long. 177° 25′ E.

This rare species seems to be restricted to the area bounded by Longitudes 115° East and 177° East and Latitudes 18° South and 15° North. Paratypes and hypotypes will be retained in the collections cited in Table 5.

Discussion: *Terebra jenningsi* resembles *T. triseriata* Gray, 1834, and *T. cumingi* Deshayes, 1857, but is readily distinguished from them. The double row of crenules forming the subsutural band of those species is highly developed into strong beads which continue throughout the growth of the shell, while in *T. jenningsi* the subsutural collar is nodular and less well defined and is progressively obsolete becoming a flatly-rounded, obscurely nodular belt. Both *T. triseriata* and *T. cumingi* have strong, raised axial ribs crossed by numerous small impressed spiral striae which serrate, occasionally bead or cancellate the peripheral area, while in *T. jenningsi* the ribs are only slightly raised or completely obsolete, the growth lines weak and dextrally arcuate, spirally encircled with about four uninterrupted rounded impressed grooves. The apical angle of *T. cumingi* is greater than that of *T. jenningsi,* while the very twisted columella and laminated columellar wall of that species are in contrast to the slightly bent columella and unlaminated columellar wall of *T. jenningsi.* The aperture of *T. jenningsi* is more flaring and lengthened, with the columella longer and less sharply bent than in *T. triseriata.* The whorls of *T. triseriata* are more numerous (in the ratio of about 3:2) than in *T. jenningsi,* and the highly developed subsutural and peripheral sculpture creates a more turreted and concave whorl than is formed by *T. jenningsi.*

The color pattern of the shell is often a helpful species-differentiating characteristic of the genus *Terebra,* though less useful in this respect with species of *Duplicaria* and *Hastula.* The basic orange color of *T. jenningsi,* with the encircling white band at the sutures continuing around the body whorl as a row of small, poorly defined white crenules at the periphery, assist in separating this species from *T. cumingi* and *T. triseriata,* both of which are basically a solid deep-amber color, with an occasional rare white or albino specimen.

This species is named in honor of Mr. A. Jennings for his generous assistance in collecting quantities of Fiji Islands specimens for study, and for having collected the specimens which first brought this species to my attention.

Terebra (Decorihastula) kilburni R. D. Burch, spec. nov.

(Plate 31, Figure 8)

Description: Shell small, with turreted, tightly-wound, flat-convex whorls, very slender in proportion to the width; basic color ivory-white, broken by a reddish-brown stain in the rib interstices which forms irregular, disconnected unevenly-sized blotches of color; ribs white or lighter color, with occasional interstices not colored; protoconch paucispiral, consisting of two and one-half conical, glassy, amber colored whorls; teleoconch sculpture of axial ribs contiguous with the sutures, with the anterior three-fourths of the whorl having about four minute, pricked punctations in the interstices; posterior punctations increase in size with shell growth to form a deeply-punctate, occasionally obsolete, subsutural groove; axial ribs straight, close-set, rounded, continue to base of shell with the interstitial striae, about ten on the penultimate whorl, also extending to base; the indistinct subsutural band formed by deep punctations of the subsutural groove is occasionally microscopically striate; an obscure white band circles

Table 5

Terebra (Triplostephanus) jenningsi

Specimen	Collection	Locality	Collector
Holotype	M. C. Z. No. 251248	Natadola, Fiji Islands	A. Jennings
Paratypes 1 - 3	Jennings Coll.	Natadola, Fiji Islands	A. Jennings
Paratypes 4 - 6	Cernohorsky Coll.	Natadola, Fiji Islands	A. Jennings
Paratypes 7, 8	R. D. Burch Coll. No.034	Natadola, Fiji Islands	A. Jennings
Paratype 9	R. D. Burch Coll. No. 521	Nadi Island, Fiji Islands	A. Jennings
Paratype 10	Cernohorsky Coll.	Vatukoula, Fiji Islands	W. Cernohorsky
Hypotype 1	R. D. Burch Coll. No. 607	Malawali Island, Sabah, Malaysia	M. Saul
Hypotype 2	M. Saul Coll., No. 387 B	Malawali Island, Sabah, Malaysia	M. Saul
Hypotype 3	R. D. Burch Coll. No. 033	Batangas Bay, Philippines	*ex* D. Dan

the body whorl at the periphery; aperture very narrow and elongate; columella twisted, with a single plication; columellar wall moderately, translucently laminated; siphonal canal recurved. Length 32.0 mm; width 5.0 mm.
Holotype: Museum of Comparative Zoology, Harvard University No. 251247
Type Locality: The holotype and 15 paratypes were collected by dredging in two to three feet off Wading Island, Fiji Islands, in July, 1962, by Mr. A. Jennings. Lat. 17° 45′ S; Long. 177° 25′ E.

Paratypes and hypotypes will be retained in the collections cited in Table 6.

Discussion: *Terebra kilburni* resembles several species of similar sculpture which include *T. columellaris* Hinds, 1844, *T. undulata* Gray, 1834, *T. turrita* (E. A. Smith, 1873), *T. fijiensis* (E. A. Smith, 1873), and *T. paucistriata* (E. A. Smith, 1873). *Terebra kilburni* is a smaller and more slender species, with more tightly wound whorls and smaller, more closely-set axial ribs than *T. columellaris* or *T. undulata.* The axial ribs of *T. paucistriata* and *T. fijiensis* are also larger and more widely spaced, and on all of the above similar species a distinct, well-formed subsutural groove separates a crenate, turreted subsutural band which does not resemble the smaller, flatter, not crenate band of *T. kilburni.* The axial ribs of *T. turrita* are sharp and widely spaced, with the interstices bluntly grooved and the whorls very turreted, while in *T. kilburni* the close-set, rounded ribs possess interstitial shallow, narrow grooves.

The color pattern of each of the above species is different from that of *Terebra kilburni.* The basic dark yellow color of *T. paucistriata* is broken by a relatively broad band of white which covers the subsutural crenules and a portion of the whorl anterior to them; the periphery of the body whorl has an obscure white band. The color and color pattern of *T. fijiensis* are similar to that of *T. paucistriata,* but sculptural differences exist between the two species. The basic white color of *T. columellaris* is obscured by brown or orange predominant on the adult whorls so that only an occasional white rib is visible, with more of the white color visible in the crenules of the subsutural band and a distinct peripheral band of white at the body whorl. The interstices of *T. turrita* rib sculpture are colored with brown in the same manner as *T. kilburni,* but the great sculptural differences distinguish these two species very readily.

This species is named in honor of Mr. R. N. Kilburn for his patient assistance and advice on the identification and synonymy of this and numerous other terebrid species.

Terebra (Dimidacus) montgomeryi R. D. Burch, spec. nov.

(Plate 31, Figure 7)

Description: Shell of medium size, moderately subulate, with turreted, flat whorls; basic color white, with flammules of a deep orange color on the early whorls coalescing to form large blotches of color on the adult whorls; the orange flammules are very concave on the posterior portion of the whorls, with the points thus formed extending to the suture and forming an irregular series of relatively large white spots on the subsutural band; axial sculpture composed only of flexuous, microscopic growth lines; subsutural groove shallow and finely punctate at the bottom, setting off a subsutural band that is slightly

Table 6

Terebra (Decorihastula) kilburni

Specimen	Collection	Locality	Collector
Holotype	M. C. Z. No. 251247	Wading Island, Fiji Islands	A. Jennings
Paratypes 1 - 5	Jennings Coll.	Wading Island, Fiji Islands	A. Jennings
Paratypes 6, 7	Natal Mus., South Africa No. 1070	Wading Island, Fiji Islands	A. Jennings
Paratypes 8 - 10	R. D. Burch Coll. No. 366	Wading Island, Fiji Islands	A. Jennings
Paratypes 11 - 14	Cernohorsky Coll.	Wading Island, Fiji Islands	A. Jennings
Paratype 15	R. D. Burch Coll. No. 649	Lomalagi, Fiji Islands	W. Cernohorsky
Paratypes 16 - 18	Cernohorsky Coll.	Lomalagi, Fiji Islands	W. Cernohorsky
Hypotypes 1, 2	M. C. Z. No. 251246	Madang, New Guinea	I. Pert
Hypotypes 3 - 10	R. D. Burch Coll. No. 302	Madang, New Guinea	I. Pert
Hypotype 11	R. D. Burch Coll. No. 479	Thursday Island, Queensland Australia	*ex* W. Eyerdam

crenate in the teleoconch whorls; progressively obsolete with growth until the band is flattened and broken only by the minute growth lines; anterior to the subsutural groove are four or five rows of unconnected microscopic punctations which give the appearance of spiral striae, with additional obsolete rows anterior to the periphery of the body whorl; aperture narrow-ovate, light-orange within; columella white, moderately twisted, with a single plication; siphonal canal recurved and bounded by a strong cord. Length 57.0 mm; width 10.0 mm.

Holotype: Museum of Comparative Zoology, Harvard University No. 251240

Type Locality: The holotype was collected in fine sand at four feet, inside the reef of Piti Bay, off Piti, Guam, Mariana Islands. Lat. 13° 27′ N; Long. 144° 43′ E.

Only the holotype and a single hypotype of *Terebra montgomeryi* are known to me. Hypotype no. 1 was collected off Natadola Island, Fiji Islands, in 1963, by Mr. A. Jennings and is in the Jennings Collection. Length 50.3 mm; width 8.7 mm.

Discussion: *Terebra montgomeryi* resembles *T. cingulifera* LAMARCK, 1822, except that the latter species has a basic color of plain yellowish-white or pinkish-white, with a spiral sculpture of four or five continuous indistinct grooves which are occasionally punctate within, while the whorls of *T. montgomeryi* are not grooved and the punctations are on the shell surface and not connected. The basic color of *T. pallida* DESHAYES, 1857, is a plain dark orange-red, with a series of about six narrow spiral grooves, not punctate within, on the penultimate whorl and a laminated columellar wall, while the columellar wall of *T. montgomeryi* is not laminated.

This species is named to honor Mr. Tom Montgomery for collecting and donating the holotype, and for his assistance with specimens of terebrids of Guam.

The limited reference literature for Fijian terebrids seems presently confined to CATE & BURCH, 1964. Collecting done subsequently to the publication of that paper, at Fiji by Mr. A. Jennings and Mr. W. O. Cernohorsky, and at Madang, New Guinea by Mrs. Isobel Pert, has resulted in a number of additions to that list, which are included here.

Duplicaria concolor (E. A. SMITH, 1873): Ann. Mag. Nat. Hist., vol. 11, p. 265; unfigured. - This is the *D. australis* (E. A. SMITH, 1873) of CATE & BURCH, 1964. The variability often exhibited by Fijian species and the similarity of *D. australis* and *D. concolor* led to the error in identification of the Fiji specimen cited. Jennings Collection.

Duplicaria raphanula (LAMARCK, 1822): Anim. s. Vert. vol. 7, p. 288, no. 16; fig.: KIENER, Icon. Coq. Viv., 1839, plt. 10, fig. 20. - Fiji Islands. Cernohorsky Collection.

Hastula castaneofusca (THIELE, 1925): Deutsche Tiefsee Exped., Gastr., prt. 2, p. 345, plt. 29, fig. 21. Madang, New Guinea. R. D. Burch Collection.

Hastula cernohorskyi R. D. BURCH, 1965.

Hastula exacuminata SACCO, 1891: I moll. terr. terz. Piem. Lig., *Terebra,* p. 18, fig.: REEVE, 1860, Conch. Icon., *Terebra,* plt. 26, fig. 143. - Madang, New Guinea. R. D. Burch Collection.

Hastula plumbea (QUOY & GAIMARD, 1832): Voy. Astrol., Moll., p. 470, plt. 36, fig. 29. - Fiji Islands. Cernohorsky Collection; Jennings Collection.

Hastula stylata (HINDS, 1844): Proc. Zool. Soc. London for 1843, p. 152; fig.: HINDS in SOWERBY, Thes. Conch., *Terebra,* plt. 44, fig. 79; 1844. - Fiji Islands. Cernohorsky Collection.

Terebra chlorata LAMARCK, 1822: Anim. s. Vert., vol. 7, p. 288. no. 14; fig.: KIENER, 1839, Icon. Coq. Viv., plt. 4, figs. 8, 8a. - Madang, New Guinea. R. D. Burch Collection.

Terebra fijiensis (E. A. SMITH, 1873): Ann. Mag. Nat. Hist., p. 266; unfigured. - Fiji Islands. Cernohorsky Collection; Jennings Collection. Madang, New Guinea. R. D. Burch Collection.

Terebra flavofasciata PILSBRY, 1921: Proc. Acad. Nat. Sci. Philadelphia, vol. 69, p. 306, plt. 12, fig. 3. Madang, New Guinea. R. D. Burch Collection.

Terebra jenningsi R. D. BURCH, 1965.

Terebra kilburni R. D. BURCH, 1965.

Terebra marmorata DESHAYES, 1859: Proc. Zool. Soc. London, p. 279; fig.: REEVE, 1860; Conch. Icon., *Terebra,* plt. 19, figs. 91a, b. - Fiji Islands. Cernohorsky Collection.

Terebra montgomeryi R. D. BURCH, 1965.

Terebra pallida DESHAYES, 1857: Journ. Conchyl., p. 87, plt. 4, fig. 3. - Fiji Islands. Cernohorsky Collection; Jennings Collection; R. D. Burch Collection.

Terebra triseriata GRAY, 1834: Proc. Zool. Soc. London, p. 62; fig.: REEVE, 1860, Conch. Icon. *Terebra,* plt. 13, figs. 52a, b. - Fiji Islands. Cernohorsky Collection. Madang, New Guinea. R. D. Burch Collection.

Provisional Check List of Terebrids Collected at Sabah, Malaysia

The terebrid fauna of Sabah, Malaysia (formerly North Borneo) is unusual because some of the species found here seemingly do not occur in the neighboring Philippine Islands. Because of this difference in species, the almost non-existent reference literature and the presently restricted collecting in the area, the citations below may be of use to students. Through the assistance of Mary Saul, who intensively collected in the area from 1960 to date, the following list of species is possible.

Symbols and abbreviations used are as follows:

(1) Northwest coast, including Jesselton and offshore islands.
(2) Kudat District, including Marudu Bay, the Malawali Channel; adjacent islands.
(3) Sandakan, the Bay area only, and Berhala Island.
(4) East coast; Semporna and offshore islands.
S Saul Collection.
B R. D. Burch Collection.

Genus *Hastula*

H. albula (Menke, 1843). (1) S no. 390; B no. 110
H. caerulescens (Lamarck, 1822). (2) S no. 214; B no. 543
H. castaneofusca (Thiele, 1925). (1) S no. 462A; B no. 632
H. concinna (Dillwyn, 1817). (1) S no. 219
H. exacuminata Sacco, 1891. (1) S no. 218; B no. 161
H. lanceata (Linnaeus, 1767). (4). S no. 516.
H. nitida (Hinds, 1844). (3). S no. 463A.
H. plumbea (Quoy & Gaimard, 1832). (3) S no. 462; B no. 550.
H. solida (Deshayes, 1857). (3) S no. 545.

Genus *Duplicaria*

D. duplicata (Linnaeus, 1758). (2), (3) S no. 215, 456; B no. 103, 544.
D. raphanula (Lamarck, 1822). (3) S no. 546.
D. spectabilis (Hinds, 1844). (1), (3) S no. 345; B no. 051.

Genus *Terebra*

T. affinis Gray, 1834. (2) S no. 216; B no. 545.
T. albomarginata Deshayes, 1859. (2) S no. 007.
T. anilis (Röding, 1798). (3) S no. 347; B no. 548.
T. areolata (Link, 1806). (1), (2), (3), (4) S no. 211; B no. 540.
T. babylonia Lamarck, 1822. (2) S no. 543; B no. 610.
T. cancellata Quoy & Gaimard, 1832. (1) S no. 346; B no. 558.
T. cerithina Lamarck, 1822. (2) S no. 216A; B no. 686.
T. chlorata Lamarck, 1822. (2) S no. 459; B no. 547.
T. cingulifera Lamarck, 1822. (2) S no. 460; B no. 687.
T. columellaris Hinds, 1844. (2) S no. 457A; B no. 549.
T. conspersa Hinds, 1844. (2) S no. 541; B no. 609.
T. crenulata (Linnaeus, 1758). (1), (2), (3), (4) S no. 210; B no. 539.
T. deshayesi Reeve, 1860. (2) S no. 385; B no. 210.
T. dimidiata (Linnaeus, 1758). (1), (2), (3), (4) S no. 213; B no. 542.
T. exigua Deshayes, 1859. (2) S no. 348A.
T. funiculata Hinds, 1844. (1) B no. 635.
T. guttata (Röding, 1798). (2), (4) S no. 515.
T. jenningsi R. D. Burch. 1965. (2) S no. 387B; B no. 607.
T. laevigata Gray, 1834. (2) S no. 387; B no. 557.
T. livida Reeve, 1860. (3) S no. 463; B no. 554.
T. longiscata Deshayes, 1859. (3) S no. 461; B no. 556.
T. maculata (Linnaeus, 1758). (1), (2), (3), (4) S no. 209; B no. 538.
T. monilis Quoy & Gaimard, 1832. (2) S no. 386; B no. 561.
T. nebulosa Sowerby, 1825. (2) S no. 457; B no. 546.
T. persica E. A. Smith, 1877. (3) S no. 503; B no. 553.
T. subulata (Linnaeus, 1767). (1), (2), (3), (4) S no. 212; B no. 541.
T. textilis Hinds, 1844. (2) S no. 008.
T. tricincta E. A. Smith, 1877. (3) S no. 465; B no. 552.
T. undulata Gray, 1834. (2) S no. 458.

Location of collections from which specimens in the present paper are cited, is as follows:

R. D. Burch Coll. (also: B) - Winton, California.
G. B. Campbell Coll. - Lynwood, California.
Cate Coll. - C. & J. Cate, Los Angeles, California.
W. Cernohorsky Coll. - Vatukoula, Fiji Islands.
T. Crake Coll. - Broome, Western Australia.
N. Currin Coll. - San Diego, California.
Harrison Coll. - A. & E. Harrison, Honolulu, Hawaii.
A. Jennings Coll. - Nadi Island, Fiji Islands.
J. Kern Coll. - Maui, Hawaii.
Miller Coll. - Suva, Fiji Islands.
MCZ - Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.
Natal Museum - Pietermaritzburg, Republic of South Africa.
San Diego Natural History Museum - San Diego, Calif.
Saul Coll. (also: S) - M. Saul, Sandakan, Sabah, Malaysia.

Teramachi Coll. - A. Teramachi, Kyoto, Japan.
Tiedeman Coll. - A. Tiedeman, Honolulu, Hawaii.
Weaver Coll. - C. Weaver, Kailua, Hawaii.
Webb Coll. - K. Webb, Chula Vista, California.

Genera and subgenera, to which various species in this paper are referred, together with their respective type species, are as follows:

Clathroterebra Oyama, 1961: Venus **21** (2), p. 188. — *Terebra fortunei* Deshayes, 1857.
Decorihastula Oyama, 1961: Venus **21** (2), p. 185 — *Terebra affinis* Gray, 1834.
Dimidacus Iredale, 1929: Austral. Zool. **5**, p. 341 — *Terebra cingulifera* Lamarck, 1822.
Terebrina Bartsch, 1923: Nautilus **37** (2), pp. 62, 63 (*non* Rafinesque, 1815, Ann. Nat., p. 145).
Duplicaria Dall, 1908: Nautilus **21**, p. 124 — *Buccinum duplicata* Linnaeus, 1758.
Diplomeriza Dall, 1919: Nautilus **33**, p. 32.
Myurellisca Bartsch, 1923: Nautilus **37** (2), p. 63.
Hastula H. & A. Adams, 1853: Gen. Rec. Moll., **1**, p. 225. — *Hastula concinna* (Dillwyn, 1817) = *Terebra strigilata* (Linnaeus) of authors.
Noditerebra Cossmann, 1896: Ess. d. Pal. Comp., **2**, p. 51 — *Terebra geniculata* Tate, 1886.
Perirhoe Dall, 1908: Nautilus **21**, p. 124 — *Terebra circumcincta* Deshayes, 1857.
Pervicacia Iredale, 1924 — *Terebra ustulata* Deshayes, 1857.
Punctoterebra Bartsch, 1923: Nautilus **37** (2), pp. 61, 63 — *Terebra nitida* Hinds, 1844.
Strioterebrum Sacco, 1891: Moll. Piem. Lig., p. 33 — *Terebra basteroti* Nyst, 1843.
Terebra Bruguière, 1789: Encycl. Méthod. Vers, vol. **1**, p. 15 — *Buccinum subulata* Linnaeus, 1767.
Triplostephanus Dall, 1908: Nautilus **21**, p. 124 — *Terebra triseriata* Gray, 1834.

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I am sincerely grateful for the generous cooperation given me over a period of many months by the individuals who have contributed so much of their time, advice and specimens toward the completion of this paper. The observations of those in the field who provided specimens with accurate locality data have added much to our knowledge of the distributional ranges of several species, while also adding to our information of species variability, ecology, and density patterns. Much additional information has been gained through the assistance extended by those who have made their collections available for study. In addition to the individuals and collections cited above, I wish to express my appreciation to Dr. A. C. van Bruggen of the Natal Museum, Dr. W. J. Clench of the Museum of Comparative Zoology, and Mr. Emery Chace of the San Diego Museum of Natural History and the San Diego Society of Natural History for advice and specimens made available to me during the course of this study.

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LITERATURE CITED

Cate, Jean M., & R. D. Burch
1964. Mitridae and Terebridae (Mollusca: Gastropoda) of Malaita, Fiji, and Bileau Island, New Guinea. The Veliger 6 (3): 139 - 147. (1 January 1964)

Hirase, Yoichiro
1917. Terebridae of the Japanese Empire. Illustr.; 131 figs.

Kuroda, Tokubei & Tadashige Habe
1952. Checklist and bibliography of the Recent marine mollusca of Japan. 210 pp.; 2 maps. Tokyo, Japan (4 April 1952)

Mant, Charles F.
1923. Mollusca from the dredging operations at Kewalo Harbor, Honolulu, 1921. Nautilus 36 (4): 120 - 123.

Oyama, Katura
1961. On some new facts of the taxonomy of Terebridae. Venus: Japan. Journ. Malacol. 21 (2): 176 - 189 (Jan. 1961)
1961. On Japanese terebrid fossils and a few new facts of the family. Venus: Japan. Journ. Malacol. 21 (3): 281 - 288 (August 1961)
1961. Biogeographical notes on Japanese Terebridae. Venus: Japan. Journ. Malacol. 21 (4): 442 - 462 (December 1961)

Pilsbry, Henry Augustus
1921. Marine mollusks of Hawaii. Proc. Acad. Nat. Sci. Philadelphia; part 9: *Terebra*, pp. 300 - 309; 1 plt. (5 January 1921)

Tinker, Spencer Wilkie
1958. Pacific sea shells; a handbook of common marine mollusks of Hawaii and the South Seas. 2nd. rev. ed.; 239 pp.; illust. C. E. Tuttle Co. Vermont.
[The auger shell family, pp. 184 - 200; 7 plts.]

Weaver, Clifton S.
1960 - 1961. Hawaiian marine mollusks; Recent and new species. pp. 1 - 36; 9 plts.

NOTES & NEWS

A. M. U.

Pacific Division

Meetings of the American Malacological Union - Pacific Division will take place in San Diego, California, June 24 through June 27, 1965. An attractive meeting site adjacent to the ocean and reasonable accommodations in dormitory facilities will be provided by California Western University. Field trips of unusual interest are being planned.

Members of the A. M. U., the A. M. U. - P. D. and all who are interested in malacology, are invited to attend the meetings and to contribute papers. Titles and abstracts for those papers must be submitted before May 1, 1965. All correspondence should be directed to the Secretary, Mrs. Barbara J. Good, 3142 Larga Court, San Diego, California 92110. Those who are not members of the AMU - PD but who wish to be placed on the meeting mailing list should include 50 cents with their request.

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BOOKS, PERIODICALS, PAMPHLETS

Van Nostrand's Standard Catalog of Shells,

by J. L. Wagner and R. Tucker Abbott. D. Van Nostrand Co., Princeton, N. J., Nov. 16, 1964. — $4.50.

Although publicity releases for this book stress establishment of valuations as its prime feature, the major usefulness, instead, may prove to be the check lists of selected groups, which are gratifyingly complete. Only a few of these are covered in this "first edition" — groups that are especially popular with collectors. The title perhaps should have included a phrase such as "Part I," for this is only the first volume in a projected series. Comprehensive coverage is for the genera *Conus, Cypraea,* and *Voluta* (all in the broad sense - *s. l.*), with more sketchy reviews of *Murex, Pleurotomaria, Strombus, Astraea,* and a few others. Listing under the broadly-conceived genera is alphabetical, by species, with citation of modern subgeneric assignment. Also included are notes as to size, available figures, geographic range, synonymy, and common names. On the latter two, there may be some differences of interpretation: Those who compare the synonymy, say, of *Cypraea* with that in the latest summary by the cowrie specialist, Dr. F. A. Schilder (The Veliger, vol. 7, no. 3, pp. 171 - 183, Jan. 1, 1965) will discover a number of discrepancies as to ranking, which is inevitable in taxonomic work. Common names are said to have been cited "when in use;" however, the term "Gastroverm" for *Neopilina* is, if not an innovation, surely not one in common use, and other similar examples could be pointed out.

Several short chapters compile useful information not readily available elsewhere, such as lists of shell clubs, of dealers, international monetary quotations, world size records, and notable shell auctions of the past.

Museum curators have traditionally shied away from the task of setting valuations on shells for a twofold reason — to avoid the possible stigma of commercialism and to forestall the troublesome requests of persons wishing to dispose of collections. A guide that would suggest valuations somewhere between the inconsistent and often high prices of dealers' sales lists and the disproportionately low prices that dealers may offer to pay for collections could be of real service to the amateur. It could also be a means of facilitating comparisons between exchange lots. Whether this first attempt will serve the intended purposes remains to be seen. The three factors cited as bases for the stated valuations are: relative abundance, the desirability to collectors, and dealers' prices. The actual formulas for balancing these factors as applied in this book are an enigma, however, when so rare a form as *Haloconcha reflexa* (unknown to most collectors and unavailable in most if not all West Coast museum collections) is priced in the "Quick list for Western North America" at 12 cents for a specimen with good locality data, 8 cents for a "data-less shell." The "Quick Lists," which are eventually to cover all the major faunal regions, are restricted as yet to three American areas — the East Coast of North America, the West Coast, and the Caribbean. Foreign exchangers who take these lists seriously may try to drive hard bargains with their American colleagues, for no American limpet or *Thais* or *Macoma* rates more than a dime in price, even with data. A differential of one or two cents between prime and "data-less" shells will not encourage collectors to go to much trouble in providing good material. One wonders if a 5-point or a 10-point scale of rarity would not have been a better compromise than the attempt at precise figures — such as 95 cents for *Haliotis rufescens* as against 40 cents for the actually much less common *H. walallensis*. The "Quick Lists," therefore, would seem to be open to much revision in future editions.

Illustrations are in the main black and white line cuts, most of them apparently culled from that classic source of fine engravings, Chenu's "Manuel de Conchyliologie." Two color plates serve as covers for the soft-bound book.

Aside from the over-deflated prices of the Quick Lists, this book should be useful for its well-organized check lists of those gastropod groups most prized by collectors. Several more volumes will be needed to complete the catalogue of Mollusca.

MK

Neogastropoda, Opisthobranchia and Basommatophora from the Ripley, Owl Creek and Prairie Bluff Formations.

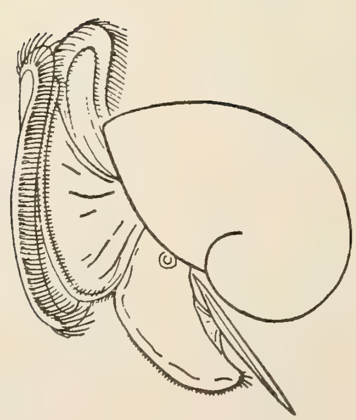
by Norman F. Sohl. U. S. Geological Survey, Professional Paper 331-B, pp. 153 - 344; plts. 19 - 52; text figs. 12 - 18; tables 1, 2.

The second part of a complete and detailed study of the rich Upper Cretaceous faunas of Tennessee and Mississippi is as well-illustrated and informative as the author's preceding contribution published in 1960 [Archeogastropoda, Mesogastropoda, and stratigraphy of the Ripley, Owl Creek, and Prairie Bluff Formations:

U. S. Geol. Surv., Prof. Paper 331-A, pp. 1 -151; plts. 1 - 18]. Two hundred and ten species, 77 of them new, are described and assigned to 95 genera and subgenera. A new genus, *Lowenstamia,* and subgenus, *Ornopsis (Pornosis),* are proposed. Fifty-two additional species are represented by material which is inadequate for any but tentative generic assignments and specific identifications.

Evolutionary, ecological, and biogeographical developments of gastropods in Late Cretaceous seas are illuminated strikingly by the Saul's analysis. Mesogastropoda normally constitute about 50% of Late Cretaceous gastropod faunas, culminating their gradual ascendancy over the dominant Archaeogastropoda of the Paleozoic. The Tertiary increase of Neogastropoda at the expense of the Mesogastropoda is anticipated, interestingly, in the unusual dominance of Neogastropoda in the Late Campanian-Maestrichtian faunas of the Ripley, Owl Creek, and Prairie Bluff formations.

ECA



THE VELIGER is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable. In the unlikely event that space considerations make limitations necessary, papers dealing with mollusks from the Pacific region will be given priority. However, in this case the term "Pacific region" is to be most liberally interpreted.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or lesser taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, will be published in the column "NOTES & NEWS"; in this column will also appear notices of meetings of the American Malacological Union, as well as news items which are deemed of interest to our subscribers in general. Articles on "METHODS & TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

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